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VOLUME 7 MAY, 1938 No 1

EVOLUTION OF AQUATIC HABITATS WITH SPECIAL REFERENCE TO THE DISTRIBUTION OF CORIXIDAE

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(*With Plate* 1 *and* 2 *Figures in the Text*)

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1. INTRODUCTION

CORIXIDAE, sometimes known as "lesser water-boatmen", are an aberrant family of the Hemiptera Heteroptera (Fig. 1). They are found in most stagnant or nearly stagnant aquatic habitats where the depth of water does not exceed about one metre, and where there is a bottom of relatively fine soil particles. There are some 30 species in the British List, many of them being common and widely distributed; moreover, nearly all, where they do occur, are found in large numbers. The group is, therefore, particularly suitable for the study of problems of distribution and the relation between a species and its environment. Before any attempt is made to explain it, the distribution of a group must be described.

It is the purpose of the present paper to describe the distribution of the species of Corixidae found in an area in the central and southern parts of the Lake District, a mountainous region with peaks rising up to 970 m. (3000 ft.) in the north-west of England. Fig. 2 shows the topography of the area and the position of the water bodies studied. Each one has been plotted on 6 in. to the mile maps, and these maps with ecological data and a collection of over 5000 specimens are now lodged in the laboratory of the Freshwater Biological Association.

The following species of Corixidae were recorded from the area:

Sigara sahlbergi (Fieb.)
S. linnei (Fieb.)
S. castanea (Thoms.)
S. striata (Linn.)
S. falleni (Fieb.)
S. distincta (Fieb.)
S. venusta (D. & S.)
S. fossarum (Leach)
S. scotti (Fieb.)
S. nigrolineata (Fieb.)
S. praeusta (Fieb.)
S. wollastoni (D. & S.)
S. carinata (Sahlb.)
Cymatia bonsdorffi (Sahlb.)
Micronecta poweri (D. & S.)
Corixa geoffroyi Leach
C. dentipes (Thoms.)
Sigara hieroglyphica (Duf.)
S. limitata (Fieb.)
S. semistriata (Fieb.)
S. concinna (Fieb.)
S. germari (Fieb.)

All the species in the two left-hand columns were found dominant in one or more localities; those in the right-hand column were never dominant.

On the advice of Mr W. E. China of the British Museum of Natural History, to whom my thanks are due, I have adopted the names used in the most recent comprehensive work on the Corixidae of West Europe (Poisson, 1935). The names referred to the genus *Sigara* in the above list will be more familiar under the name "*Corixa*", and the genus *Micronecta* will be more familiar under the name "*Sigara*".

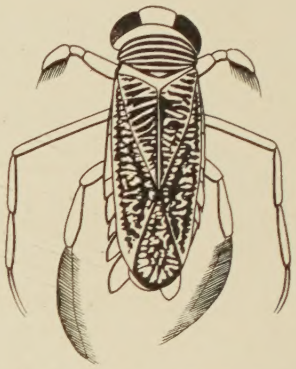

Fig. 1. Sigara scotti (×75)

I am indebted to Mr G. A. Walton of Bristol University for the identification of *Micronecta poweri*. In two papers on the fauna of Windermere this species has been referred to as *Sigara minutissima* (Moon, 1934, 1936.)

2. Methods

The collections were made with a hand-net since in many localities the bugs were so sparse that a quantitative grab would not have secured a significant number. Where there was more than one type of littoral plant community in a single body of water, a station was worked in each. At all stations an attempt

---

Key to Fig. 2.

1. Brown Cove Tarn
2. Red Tarn
3. Knott's Dock Tarn
4. Blea Tarn (Wythburn)
5. Harrop Tarn
6. Grisedale Tarn
7. Brother's Water
8. Styhead Tarn
9. Sprinkling Tarn
10. Stickle Tarn
11. Codale Tarn
12. Easedale Tarn
13. Blindtarn Moss
14. Whitemoss Reservoir
15. Blea Tarn (Langdale)
16. Lingmoor Tarn
17. Little Langdale
18. Elterwater
19. Loughrigg
20. Slew Tarn
21. Loughrigg 10
22. Low Water
23. Tarn Hows
24. Rose Castle Tarn
25. Arnside Tarn
26. Stephen How
27. Barngates Quarry
28. Lost Tarn
29. Blelham Fishpond
30. Blelham
31. Clay Pond
32. Monk Coniston 1
33. High Man Tarn
34. Goosefoot Tarn
35. Wray Mires Fishponds
36. Hodson's Tarn
37. Robinson's Tarn
38. Wray Mires Tarn
39. Wise Een Tarn
40. Wise Een Fishpond
41. Three Dubs Tarn
42. Moss Eccles Tarn
43. School Knotts Tarn
44. Cleabarrow Tarn
45. Crook Reservoirs
46. Rather Heath Tarns
47. Lindeth Tarn
48. New Tarn
49. Knipe Tarn
50. Gill Head Fishpond
51. Gill Head Reservoir
52. Podnet Tarn
53. Little Ludderburn Tarn
54. Kirby Quarries
55. Knittleton Lake
56. Great Green Hows Reservoir
57. Helton Lake

Fig. 2. Sketch-map of the Central and Southern portions of the Lake District. Contours 200, 1000, 2000 and 3000 ft. Lakes and tarns from which Corixidae were recorded are shown in black; lakes and tarns where no Corixidae were found or where no collecting has been done are shown in outline. The position of pools is indicated by a cross.

For key see opposite page.

was made to collect 20 to 30 Corixids within the smallest possible area. Since it is unlikely that one species can escape a pond net more readily than another, figures for each species in one catch are strictly comparable, but the total numbers for each catch give little idea of the abundance of the bugs at the station where the catch was made.

In order to obtain a physical estimate of the nature of the soil underlying the water, the percentage of organic matter in the soil (subsequently referred to as % o.m.s.) was measured by the ignition of a dried sample. This method is reliable, as calcium carbonate is present in negligible amounts; but the figures must be treated as approximate, since it was not possible to examine sufficient samples to eliminate local variations in the % o.m.s. in each locality, and a further error was introduced by the difficulty of freeing the samples from living roots. The nitrogen content of some soil samples was determined by Kjeldahl's method. In calculating the carbon/nitrogen ratio the carbon content of the soil is taken to be half the organic matter. The *p*H value of the water was taken in the field by means of indicators and comparison with standard buffer solutions. The colour of the water was measured by the methyl orange method of Ohle (1934).

3. Aquatic habitats in the area

Conditions are singularly uniform throughout the area. The rocks, Borrowdale volcanic series and Bannisdale slates, are hard, the vegetation is chiefly rough grassland or moorland, and the waters are poor in salts, particularly those of calcium. The bodies of water fall conveniently into three classes: (*a*) pools, (*b*) tarns, (*c*) lakes.

Pools are shallow collections of water lying in rock crevices or in hollows in thick layers of peat; while tarns and lakes are collections of water lying in eroded rock basins and/or held up by dams which may be of glacial or artificial origin. The distinction between tarns and lakes is not clear cut, but in general tarns are smaller and shallower, fed by smaller streams, and situated on the top or side of a hill, while lakes are larger and deeper, fed by rivers and situated in the main valleys. In the area studied the surface area of the tarns ranges between 500 and 200,000 sq. m. and the depth probably seldom exceeds 10 m. The surface area of lakes ranges between 90,000 and about 15,000,000 sq. m. and the deepest (Windermere) has a maximum depth of 67 m.

This classification on physiographic features has the merit of convenience and simplicity, but before studying these three classes of water body as environments inhabited by animals and plants it is desirable to look for some more fundamental distinction between them.

It has been shown by Pearsall (1920, 1921) that one such distinction is the *proportion of bases present in the water*, a factor dependent on the rate at which *silting* is taking place. This affects all aspects of lake biology, but for the

Phot. 1. Grisedale Tarn. A barren natural tarn. *Corixa wollastoni* occurs in the small pool near the end of the tarn.

Phot. 2. Stephen How. Habitat of *Sigara scotti*.

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present purpose it is necessary to consider only the relation between silt and the subaquatic soils.

Every aquatic habitat is continually evolving, a process which, in general, means that soil is accumulating and that the locality is, therefore, gradually filling up. This accumulating soil is made up partly of vegetable remains and partly of inorganic silt. Vegetable remains contribute organic matter and silt brings with it bases which enable this organic matter to be decomposed. Accordingly the amount of silt relative to the amount of vegetable remains determines the rate at which the percentage of organic matter in the soil (% o.m.s.) increases. The soil is first colonized by submerged plants, but with the increase in the % o.m.s. these submerged plants are replaced by species with floating leaves, which in their turn give place to others with an emergent habit. It is found that the component species in such a succession vary in different places, and that the factors determining what species shall make up the succession in any one place are related to the rate at which the % o.m.s. is increasing.

In the waters of the Lake District plant successions culminate in five different species of emergent. *Typha latifolia* grows on soils where the rate of increase of % o.m.s. is low, *Phragmites communis* where it is more rapid; while still higher rates of increase result successively in the appearance of *Scirpus lacustris*, *Equisetum limosum* and *Carex inflata*. Since most bodies of freshwater ultimately become dry land it is possible to go a stage further. Soils where the rate of increase of the % o.m.s. is low ultimately support woodland, those where it is high, moorland.

Thus study of the vegetation shows that a subaquatic soil varies in two important factors: on the one hand the *quantity* of organic matter present, on the other the *quality*, this latter depending on the rate at which the percentage of organic matter has increased. During the present investigation the actual percentage of organic matter present in the soil has been measured directly and its quality has been assessed from the species of plant found. The classification of water bodies may now be reconsidered from the point of view of the % o.m.s. and the rate at which it is increasing.

In *pools* there is little or no silting and therefore little decomposition of plant remains. There is a rapid increase in the % o.m.s. and a high figure is soon reached and thereafter maintained. Where there is a highly organic soil from the beginning (peat pools) the high value is merely maintained. *Tarns* receive some silt, but since their feeding streams are seldom of any size, only small quantities are brought in, and they too have a high % o.m.s. They become overgrown with *Carex* (e.g. Robinson Tarn) and finally give rise to moorland (e.g. Blindtarn Moss). In *lakes*, on the other hand, gradual weathering of the drainage area yields an abundant supply of silt and the % o.m.s. tends to remain low. The characteristic emergent plant is *Phragmites*. The ultimate end of a lake is probably moorland too (Rankin, 1911) for the growth

of large beds of *Phragmites* checks the flow of water, silt is available in decreasing quantity, the % o.m.s. increases rapidly and except in the neighbourhood of the stream channels (e.g. Rusland Moss) *Carex* becomes the dominant plant. However, it is convenient to distinguish tarns and lakes in the Lake District as bodies of water where, except in the extreme stages, *Carex* and *Phragmites* respectively are the dominant emergent plants.

Independent of the rate at which the % o.m.s. is increasing, the rate at which soil accumulates in any body of water will vary from place to place and so different places will be at different stages of evolution. The stage of evolution may be roughly gauged from an inspection of the surroundings and it is also indicated by the nature of the vegetation, whether submerged, floating leaved or emergent. From collections made at stations in different stages of evolution it is, therefore, possible to work out successions of animal species.

4. Distribution of corixidae

(*a*) *General account*

There is evidence that the percentage of organic matter in a soil is also an important factor in the distribution of certain species of Corixidae. Further there is, as in plants, a succession of species as the % o.m.s. increases, and the species making up a succession are different at different rates of increase. Since the rate of increase of the % o.m.s. can only be roughly gauged by the species of plant growing, and since the superficial layers of soil on which the Corixids are found are those most liable to local variation in the % o.m.s., an exact correlation between the % o.m.s. and the species of Corixid is not to be expected. Nevertheless, the results suggest that there is a definite correlation between the two. At present the evidence is based entirely on field observations, and no attempt has been made to determine the nature of the relation between the type of soil and the species of Corixids living on it.

Most of the evidence obtained during the present investigation relates to the succession of species under conditions where the rate of increase of the % o.m.s. is rapid. It is taken from collections made in a number of reed-beds in Windermere and in many tarns and pools. Although Windermere is a relatively advanced lake and therefore receives much silt, most of the reed-beds are situated in bays which are fed by quite small streams. As a result, development of the bed tends to produce increasingly stagnant conditions within itself, the silt supply is reduced, and the % o.m.s. increases rapidly, ultimately producing a soil of high organic content resembling that found in tarns. Similarly, conditions over the greater part of many tarns approach those found in pools, and therefore these three types of water body represent successive stages of evolution under conditions where the rate of increase of the % o.m.s. is rapid.

Different reed-beds in Windermere are at different stages of evolution. Primitive beds, that is those with a low % o.m.s., are inhabited by *Sigara striata* and *Micronecta poweri*, a species which is found on all exposed shores, though most abundant on sand. In more advanced beds with a higher % o.m.s., *M. poweri* is not found, and *Sigara striata* is joined by *S. distincta* and *S. fossarum*, two species which in beds of yet higher organic content tend to replace *S. striata*. In beds with the highest % o.m.s., *S. scotti* is the dominant species.

S. distincta and *S. fossarum* are found in a certain number of tarns but only at stations where the % o.m.s. is relatively low. At other stations where it is higher they are replaced by *S. scotti*. Where emergent vegetation, clearly the last stage in the evolution of a body of water, provides thick cover *S. castanea* is the only species found. In pools *S. scotti* occurs where vegetation is sparse or absent; *S. castanea* where vegetation is thick.

Under conditions where the rate of increase of % o.m.s. is rapid there is, therefore, the following succession of Corixid species:

$$\textit{Micronecta poweri} \rightarrow \textit{Sigara striata} \rightarrow \left\{\begin{matrix}\textit{S. distincta}\\ \textit{S. fossarum}\end{matrix}\right\} \rightarrow \textit{S. scotti} \rightarrow \textit{S. castanea}.$$

There is unfortunately much less evidence about the succession of species under conditions where the rate of increase in the % o.m.s. is low. In this area such conditions are only maintained in reed-beds situated right at the mouth of a large stream. It seems probable, however, that *S. linnei* dominates such reed-beds and that at a later stage of evolution when willows have appeared and water is confined to marshy pools *S. sahlbergi* is the characteristic species. It appears to be associated with the presence of dead leaves under stagnant conditions. Although the evidence about this succession in the Lake District is very meagre, it is confirmed by collections made in the Little Sea, Studland (Diver and others), and it is noteworthy that Hutchinson (1926) collecting in Wicken Fen, a region where bases are abundant, records *S. striata* and *S. fossarum* from the lodes and more open stations, and *S. linnei* and *S. sahlbergi* from the *Phragmites* beds.

In eleven tarns there is a succession:

$$\textit{Sigara scotti} \rightarrow \textit{Cymatia bonsdorffi} \rightarrow \textit{S. linnei}$$

and with it is associated a fourth species, *S. praeusta*, whose relation to the others is still obscure. The only apparent difference between these tarns and the rest is that they all receive organic matter from some external source, either from dead leaves or animal fouling.

As pointed out above, pools are inhabited by *S. scotti* and *S. castanea*, but this only refers to those pools which lie below an altitude of approximately 450 m. (1500 ft.). Above this altitude *S. wollastoni*, *S. nigrolineata*, and occasionally *S. carinata* are the dominant species.

The evidence on which these conclusions are based may now be considered more fully, records for each of the three classes of water body being treated separately.

(*b*) *Detailed account*

(1) *Lakes.*

Most of the work has been done in the north basin of Windermere; but collections have also been made from other bodies of water which, although commonly called tarns, must (since the characteristic emergent plant is *Phragmites*) be considered lakes in the light of the definition already given (p. 6). In parts of Windermere sheer rock-faces may still be found, but along most of the shoreline they are either weathered to give the stony "Bannisdale shore" or are covered by glacial drift. Where headlands afford protection from wave action finer deposits cover the bottom, and here are found beds of vegetation comprising either plants confined elsewhere to deeper water (e.g. *Myriophyllum*, etc.), or plants with an emergent habit. In Table 1 these beds are arranged in order of the % o.m.s. It will be seen that *Phragmites* is the only plant in beds where the % o.m.s. is low, and that, as the percentage increases, *Scirpus* and *Carex* appear as well, indicating conditions of rapid increase.

Micronecta only occurs in beds where the % o.m.s. is very low. Its distribution is considered in detail later. The species of *Sigara* are only found under the sheltered conditions of the reed-beds, and it will be seen from the table that with the increase in the % o.m.s. there is a change in the composition of the Corixid population. *S. striata* is the only species in the beds where the % o.m.s. is low; in beds where the % o.m.s. is higher it is joined and finally to some extent replaced by *S. distincta* and *S. fossarum*, while in the beds where the % o.m.s. is highest *S. scotti* is the dominant species. A similar relationship between the species is found in the other lakes studied (see Table 2).

Evidence about the succession under conditions where the rate of increase of the % o.m.s. is low is only forthcoming from two small lakes, both with a complete ring of *Phragmites* round the shores, and from two localities in large lakes. Helton Lake is fed by a river, and there is clearly an abundant supply of silt. Knittleton Lake is fed by a small stream but, although the development of reed-beds is extensive, *Phragmites* has not been replaced, and this indicates a low rate of increase of the % o.m.s. The dominant species in both lakes is *Sigara linnei*.

Where the rate of increase of the % o.m.s. is low a reed-bed is succeeded by a *Salix-Phragmites* swamp. Such swamps are found on the deltas of the main inflow of Esthwaite and the Blelham Beck, one of the larger feeders of Windermere. Water persists in a few places on these deltas and the only species of Corixid found is *Sigara sahlbergi*.

The distribution of *Micronecta poweri* may be considered in more detail. The records, summarized in Table 3, are largely taken from the data which Mr

Table 1

Locality	Vegetation	Nature of bottom	% o.m.s.	Date	*M. poweri*	*S. striata*	*S. distincta*	*S. fossarum*	*S. scotti*	*S. falleni*	*S. sahlbergi*
Brathay Bar	*Phragmites*	Gravel	—	17 Aug. 1936	—	**15**	—	—	—	—	—
Brathay Bay N.	,,	Sand	3·0	7 June 1936	**50**	**11**	—	—	—	—	—
Whitecross Bay E.	,,	,,	4·0	6 July 1936	**100**	**28**	—	—	—	—	—
Brathay Mouth E.	,,	,,	5·5	12 Mar. 1937	—	**19**	2	—	—	—	—
Sandy Wyke N.	,,	,,	6·5	7 June 1936	**35**	**17**	1	—	—	—	—
Sea Mew Bay	*Littorella*	,,	6·5	10 Aug. 1936	**35**	3	—	—	—	—	—
Littorella sward M.	*Phragmites*	,,	6·5	6 Dec. 1936	—	**17**	—	—	—	—	—
Littorella sward S.	*Myriophyllum*	Washed drift	6·5	6 Dec. 1936	—	**42**	—	—	—	—	—
Pull Wyke Stream	*Phragmites, Equisetum*	Sand	9·3	1 June 1936	—	**11**	—	—	—	3	—
Ecclerigg Bay	*Myriophyllum*	,,	10·0	4 Dec. 1936	—	**18**	—	—	—	—	—
Gale Naze W.	*Phragmites, Scirpus*	,,	11·5	15 Oct. 1936	—	**17**	4	2	—	—	—
Whitecross Bay W.	*Phragmites*	Clay	15·0	6 Dec. 1936	—	**70**	**25**	2	—	—	—
Waterhead E.	*Scirpus, Juncus*	Sand	15·5	12 Mar. 1937	—	**20**	**40**	—	—	—	—
Whitecross Creek	*Carex*	Mud	19·0	6 Dec. 1936	—	**24**	3	**10**	—	—	8
Fisherty Bay	*Myriophyllum*	Debris	22·0	21 Apr. 1936	—	**15**	**17**	—	—	—	—
Bee Bay a.	*Phragmites, Carex*	Clay	22·4	2 Dec. 1936	—	4	1	**18**	—	3	—
Congo Mouth W.	*Phragmites, Scirpus, Carex*	Fibrous	22·5	21 Feb. 1937	—	**23**	**29**	**12**	—	4	—
Congo	*Callitriche*	Mud	30·0	4 Oct. 1935	—	**28**	**13**	**10**	—	—	—
Brathay Bay W.	*Scirpus*	Sand	31·0	15 Oct. 1937	—	**30**	5	—	—	—	—
Pull Wyke BH.	*Phragmites, Carex*	Fibrous	32·5	24 Nov. 1936	—	3	**13**	8	—	—	—
Congo Mouth E.	*Scirpus*	Debris	35·5	4 Apr. 1937	—	**12**	**27**	3	—	2	—
Pull Wyke Swan	*Phragmites, Equisetum, Carex*	Mud	43·0	21 Feb. 1937	—	8	6	**18**	—	**12**	—
Congo Mouth N.	*Phragmites, Scirpus, Equisetum, Carex*	Fibrous	44·5	24 Nov. 1936	—	1	**16**	**15**	—	—	—
Union Bay	*Phragmites, Carex, Menyanthes*	Sand and debris	49·0	25 Oct. 1936	—	**9**	**9**	—	**18**	—	—
Bee Bay c.	*Phragmites, Scirpus*	Fibrous	51·0	2 Dec. 1936	—	**7**	**9**	**10**	—	1	—
Gale Naze E.	*Phragmites, Equisetum, Carex*	Mud	52·0	20 Aug. 1936	—	**32**	3	—	**35**	—	—

Figures in heavy type in Tables 1, 2, 5 and 6 are the dominant and subdominant species. In all except a few border-line cases, the rule has been to count those where the number (*a*) exceeded 10 and (*b*) exceeded 33 % of the number of the most abundant species.

Table 2

Note. Habitat subdivisions (*a*) etc. refer to field survey data on specimen labels.

Locality	Vegetation	Date	*S. striata*	*S. distincta*	*S. fossarum*	*S. scotti*	*C. bonsdorffi*	*S. venusta*	*S. falcini*
Little Langdale	*Scirpus*	25 Feb. 1936	**14**	—	—	—	—	—	—
Elterwater	(*a*) *Phragmites, Equisetum*	26 Feb. 1936	**42**	—	—	—	—	—	—
	(*b*) *Scirpus*	26 Feb. 1936	**26**	5	**10**	—	—	3	—
Grasmere	*Phragmites, Scirpus, Equisetum, Carex*	6 Mar. 1936	**11**	**14**	5	—	4	—	—
Rydal	*Phragmites, Equisetum, Carex*	5 June 1936	1	—	3	—	1	—	—
Esthwaite	(*a*) *Phragmites*	12 Mar. 1936	6	—	1	—	—	—	1
	(*b*) *Phragmites, Carex*	12 Mar. 1936	5	—	—	**17**	—	—	1
Blelham	*Phragmites, Carex*	18 Mar. 1936	**10**	—	**16**	—	—	—	—
Loughrigg	*Phragmites, Carex*	16 Oct. 1935	7	—	5	—	—	—	—

Table 3

Locality	Nature of substratum	Number of hauls	Number of hauls in which *Micronecta* found	Greatest number of *Micronecta* in one haul	Average number of *Micronecta* per haul
Bays 1 to 4	Exposed Bannisdale shore	21	4	2	1·25
South of Boathouse 3	Sheltered Bannisdale shore. Small tufts of *Myriophyllum* and filamentous green algae	9	7	30	12
Boundary Crag to Epley Head	Exposed drift shore	14	2	5	3
High Wray Bay	Sandy shore. Sparse *Littorella*	12	6	6	3
Sandy Wyke	Stony shores with sand and silt	119	56	27	2·3
	Sandy shore. Sparse *Littorella*	19	5	—	1·5
	Phragmites bed	15	3	1	1
	Scirpus bed	15	3	11	6
	Littorella sward, 3 ft.	2	0	—	—
	Littorella sward, 4 ft.	4	4	1	1
	Littorella sward, 5 ft.	3	3	1	1

H. P. Moon, who has made detailed surveys of the exposed shores of Windermere, has kindly put at my disposal. The hauls covered, where possible, an area of 1 sq. ft. (0·09 sq. m.) The survey of the exposed shore was carried out during July and August, the months when *Micronecta* is most abundant; the survey of the silted shore (Pull Wyke) extended over a whole year. *Micronecta* occurred down to a depth of 5 ft. (1·5 m.) but was most numerous between 0 and 2 ft. (0·6 m.). Subsequent collections by the writer with a hand net over the drift shore between Boundary Crag and Epley Head showed that *Micronecta* occurred in moss (*Fontinalis*) growing on stones close to the water's

edge and in a small patch of *Juncus articulatus*, but not elsewhere. The occurrence of *Micronecta* in the *Scirpus* bed does not agree with observations from other reed-beds (see Table 1). It appears from Mr Moon's notes, however, that it only occurred on sandy patches.

The following collections were made with a hand grab covering an area of 1 sq. ft. (0·09 sq. m.).

Table 4

Locality	Vegetation	Date	Bottom	Depth in.	Number of *Micronecta*
"Littorella sward"	*Littorella*	12 Aug. 1936	Sand	5	74
"Littorella sward"	*Littorella*	12 Aug. 1936	Sand	5	20
Brathay Bay N.	*Phragmites*	20 Aug. 1936	Sand	15	11
Brathay Bay N.	*Phragmites*	20 Aug. 1936	Sand and dead leaves	9	0
Fisherty Bay	*Littorella*	21 Aug. 1936	Sand and gravel	26	4
Fisherty Bay	*Myriophyllum*	21 Aug. 1936	Sand	17	0
Fisherty Bay	*Potamogeton natans*	24 Aug. 1936	Vegetable debris	18	0
Fisherty Bay	*Littorella*	24 Aug. 1936	Gravel	6	3

The "*Littorella* sward" is an extensive area of sand and gravel. *Littorella* is abundant and grows right up to the water's edge, and small patches of *Myriophyllum* and filamentous green algae also occur. The grab stations were placed in the most favourable situations for *Micronecta* after a preliminary exploration with a hand net. This insect was also found in large numbers at depths of 2 and 3 ft. (0·6 and 0·9 m.) in thick filamentous green algae on a shingle spit.

Micronecta poweri is, therefore, found on all exposed shores in small isolated communities where local conditions afford some degree of shelter. It reaches its maximum abundance on moderately exposed sandy shores with thick vegetation, extends to the more exposed reed-beds, but disappears when organic matter begins to accumulate.

(2) *Tarns.*

Tarns fall conveniently into two classes according to the mode of origin: natural tarns of glacial origin, and artificial tarns formed by a recent artificial dam. The following natural tarns have been investigated: Low Water, Blea (Langdale), Sprinkling, Styhead, Lingmoor, Stickle, Codale, Easedale, Blea (Wythburn), Knott's Dock, Grisedale (Helvellyn) (Pl. 1, phot. 1), Red (Helvellyn), Scales and Bowscale. With the exception of Lingmoor Tarn, which has reached an advanced stage of evolution and has nearly filled up, all are barren of Corixids. Their stony shores, devoid of vegetation, are not suitable for the existence of these insects, which appear to require a soft substratum. On the other hand, the artificial tarns (Pl. 1, phot. 2) usually have a soft bottom of recently flooded, terrestrially formed, peat, and here Corixids are abundant.

It should be noted that every tarn from which records have been made is below 450 m. (1500 ft.) and the altitude factor, important in pools, does not call for consideration.

The following species of Corixids were recorded in tarns, the numbers in brackets indicating the number of stations at which each one was found. Records are taken from 63 stations in 37 tarns.

Sigara scotti	(42)	*Sigara venusta*	(4)
S. castanea	(26)	*S. limitata*	(2)
S. distincta	(23)	*Corixa geoffroyi*	(2)
Cymatia bonsdorffi	(21)	*C. dentipes*	(1)
Sigara linnei	(19)	*Sigara hieroglyphica*	(1)
S. fossarum	(15)	*S. semistriata*	(1)
S. praeusta	(12)	*S. nigrolineata*	(1)
S. striata	(8)	*S. wollastoni*	(1)
S. sahlbergi	(4)	*S. germari*	(1)
S. falleni	(1)		

The numbers of the species in the right-hand column never amounted to more than a few per cent. of the total population and they are not considered further. The distribution of the remaining species is shown in more detail in Tables 5 and 6.

Soil conditions in these tarns are less simple than in Windermere. In the first place the soil is of terrestrial instead of subaquatic origin, and is therefore somewhat different in character; in the second place it contains, at the beginning of the life of the tarn, about 50% of organic matter. This value may increase in the usual way or decrease owing to decomposition brought about by the deposition of silt. Although this makes the actual course of evolution more involved, the following important facts emerge. Table 5 shows 22 tarns set out with the Corixid fauna, the % o.m.s. and other details at one or more stations. The value at the station with the lowest % o.m.s. is used to arrange the tarns which are thus set out in order of descending minimum organic content. In any tarn there may be one, two or three of the following types of habitat:

(*a*) An area where the % o.m.s. is relatively low (8–50%). Such areas are usually near a stream mouth where there is a supply of silt which has enabled the original peat to be decomposed. These areas have a thick growth of vegetation made up of such plants as *Lobelia dortmanni*, *Myriophyllum* sp., *Callitriche* sp., *Potamogeton natans*, *Castalia alba*, *C. minor* and *Equisetum limosum*. The dominant species of Corixids in these areas are *Sigara distincta*, *S. fossarum* and *S. scotti*.

(*b*) An area where the % o.m.s. is relatively high (23–83%). Such areas are either places where the % o.m.s. has increased owing to silting having been arrested by the growth of plants, or places where the original peat has undergone little change. Typical plants are *Juncus fluitans*, *Apium inundatum*, *Utricularia* sp., *Menyanthes trifoliata*, *Potamogeton natans* and *Callitriche* sp. The dominant species of Corixid is *Sigara scotti*.

Table 5

Note. Habitat subdivisions (*a*) etc. refer to field survey data on specimen labels.

Tarn	*p*H of water	Vegetation at stations	% o.m.s.	Date	*S. scotti*	*S. castanea*	*S. fossarum*	*S. distincta*	*S. striata*	*C. bonsdorffi*	*S. linnei*	*S. praeusta*
Barngates Quarry	—	*Carex*	—	1 Apr. 1936	—	**19**	—	—	—	—	3	—
Whitemoss Reservoir	—	*Sphagnum*	—	27 Nov. 1935	—	**16**	—	—	—	—	—	—
Wray Mires Fishpond 1	5·8	(*a*) *Sphagnum* and *Juncus*	81	13 Jan. 1937	5	**24**	—	—	—	—	—	—
		(*b*) *Carex* and *P. natans*	83	13 Jan. 1937	**30**	—	—	—	—	—	—	—
Stephen How	—	*Menyanthes*	80	25 Mar. 1936	**41**	—	—	—	—	—	—	—
Wray Mires Fishpond 2	5·8	(*c*) *Iris*	78	13 Jan. 1937	2	**11**	—	—	—	—	—	—
		(*b*) *P. natans*	72	13 Jan. 1937	**24**	3	—	—	—	—	—	—
Wray Mires Fishpond 3	5·6	*Juncus*	77	13 Jan. 1937	1	**25**	—	—	—	—	—	—
Arnside	6·8	*P. natans*	71	9 Jan. 1937	**28**	—	—	1	—	—	—	—
Lingmoor	5·7	*Utricularia*	67	3 Oct. 1936	**25**	—	—	—	—	2	—	—
Gill Head Fishpond	6·6	*Littorella*	53	20 Feb. 1936	**56**	—	—	—	1	—	—	—
Wray Mires	6·8	(*b*) *P. natans*	50	15 Mar. 1936	**11**	3	**30**	**9**	—	—	—	—
		(*d*) Thin *Carex*	62	13 Nov. 1936	**35**	2	6	1	—	—	—	—
		(*a*) *Carex* and *Juncus*	85	17 Jan. 1937	2	**31**	1	—	—	—	—	—
Cleabarrow	6·8	*Carex*	48	4 Feb. 1937	**22**	—	—	**18**	—	—	—	—
School Knotts	7·0	(*a*) *Littorella*	44	7 Mar. 1936	**16**	3	—	—	—	—	—	—
		(*b*) *P. natans*	43	24 Feb. 1937	**25**	3	—	3	—	1	2	1
		(*c*) *Carex*	63	7 Mar. 1936	—	**32**	—	—	—	—	2	—
Wise Een Fishpond	6·8	*Littorella*	42·5	28 Oct. 1936	**57**	—	—	1	2	—	—	—
Three Dubs	6·4	(*a*) *Callitriche*	38	27 July 1936	**112**	7	—	—	—	—	—	—
		(*b*) *Juncus*	67	27 July 1936	5	7	—	—	—	—	—	—
Birket Houses	5·7	*Apium* and *Myriophyllum*	37	29 Feb. 1936	2	**13**	—	—	—	—	—	—
Lost	—	(*x*) *P. natans*	29·5	12 Nov. 1936	3	—	**12**	3	—	—	1	4
		(*z*) Bare mud	35·5	12 Nov. 1936	—	—	**33**	1	—	—	—	—
		(*y*) Thick *Carex*	70	12 Nov. 1936	—	**11**	—	—	—	—	**14**	—
Wise Een	6·9	(*c*) *Littorella*	29·5	28 Oct. 1936	**19**	—	—	—	—	—	—	—
		(*h*) Thin *Carex*	28	12 Feb. 1937	**31**	—	**13**	5	6	—	—	—
		(*i*) *Carex* and *P. natans*	32	12 Feb. 1937	**18**	—	**17**	**9**	—	—	—	—
		(*e*) Thick *Carex*	55	13 Nov. 1936	**95**	—	14	2	1	—	—	—
		(*b*) *Juncus*	89	28 Oct. 1936	**19**	**15**	—	2	—	—	—	—
Blelham Fishpond		(*a*) *Myriophyllum* and *P. natans*	—	23 Feb. 1936			**17**	—	**19**			—
		(*b*) *Juncus*	27	5 Oct. 1935	1	1	**47**	—	8			—
Green Hows Reservoir	6·7	*P. natans*	23	23 Sept. 1936	**24**	—	—	—	—	—	—	—
Moss Eccles	6·8	(*c*) Thin *Carex*	24	12 Feb. 1937	**36**	—	1	**12**	—	—	—	—
		(*d*) *P. natans*	64	11 Oct. 1936	**22**		2	1		—	—	—
Gill Head Reservoir	6·7	*J. fluitans*	12	20 Feb. 1936	**67**	—	—	2	—	3	—	—
Clay Pond	—	Bare mud	8	2 Oct. 1935	10		**104**	**48**	—	—	2	—

Table 6

Note. Habitat subdivisions (*a*) etc. refer to field survey data on specimen labels.

Tarn	*p*H of water	Vegetation at stations	% o.m.s.	Date	*S. scotti*	*C. bonsdorffi*	*S. linnei*	*S. praecsta*	*S. distincta*	*S. sahlbergi*	*S. fossarum*	*S. castanea*
Rather Heath 6	7·0	(*c*) Thin *Carex*	20	19 Dec. 1936	**23**	6	—	1	1	—	—	—
		(*d*) Thick *Carex*	42	19 Dec. 1936	—	**14**	2	2	—	—	—	—
Rather Heath 1	7·0	(*a*) *Apium*	—	29 Nov. 1936	**23**	4	—	—	1	—	—	4
		(*d*) *Carex*	49	19 Dec. 1936	—	**11**	3	6	2	—	**19**	—
		(*b*) *Carex*	—	29 Nov. 1936	1	**14**	4	—	—	—	1	—
Little Ludderburn	7·0	(*a*) Bare mud	76	11 Sept. 1936	**28**	—	—	—	—	—	—	—
		(*b*) *Callitriche*	68	11 Sept. 1936	8	**11**	—	—	2	—	—	—
		(*c*) *Carex*	—	29 Feb. 1936	—	**65**	—	—	1	—	—	—
New Slew	7·0	*Callitriche* and *Juncus fluitans*	19·5	28 Sept. 1936	6	**19**	1	8	1	—	—	3
	6·3	(*b*) *P. natans*	76	6 Apr. 1936	4	**44**	4	**24**	**37**	—	—	—
		(*a*) *Juncus*	73	7 Jan. 1937	—	**12**	2	—	5	5	—	—
		(*c*) *Carex*	90	7 Jan. 1937	—	2	**11**	—	—	—	—	—
Lindeth	6·9	(*e*) Bare mud	29	1 Jan. 1937	**29**	**12**	—	—	—	—	—	1
		(*c*) Thin *Carex*	73	1 Jan. 1937	**31**	5	1	3	—	—	—	1
		(*d*) Thick *Carex*	92	1 Jan. 1937	3	**12**	**11**	3	—	—	—	4
		(*b*) *Carex* and *Callitriche*	—	6 Dec. 1936	—	—	**30**	**16**	—	1	—	3
Rose Castle	—	*Carex*	69	19 Feb. 1936	—	5	**35**	—	—	—	—	5
Podnet	7·0	*Myriophyllum*	65	11 Sept. 1936	6	4	—	**13**	—	—	—	—
High Man	6·7	*Carex*	78	19 Mar. 1936	—	—	—	**16**	—	—	—	—
Robinson	5·8	(*a*) *Carex* and *J. fluitans*	—	6 Apr. 1936	5	—	2	—	—	—	—	**48**
		(*b*) *Carex*	—	17 Jan. 1937	9	—	**10**	—	—	—	—	**19**
Lost Tarn		See Table 1	—	—	—	—	—	—	—	—	—	—

(*c*) An area with a high % o.m.s. (37–89 %) and a thick growth of *Sphagnum* sp. or *Carex* sp. The dominant species is *Sigara castanea*.

The appearance of a thick bed of *Sphagnum* or *Carex* is clearly the last stage in the evolution of an aquatic habitat. *Sigara castanea* must, therefore, come after *S. scotti* in the evolutionary succession. With an increase in the % o.m.s. *S. scotti* replaces *S. distincta* and *S. fossarum* and there is, therefore, in tarns the following succession of Corixid species:

$$\left.\begin{matrix} S.\ distincta \\ S.\ fossarum \end{matrix}\right\} \rightarrow S.\ scotti \rightarrow S.\ castanea.$$

The figures shown in Table 5 appear to justify this general conclusion but the correlation between the values for the % o.m.s. and the species of Corixids found is not at all close. This is, perhaps, largely due to the absence of an accurate method of assessing the quality of a soil, that is, of obtaining a knowledge of the rate at which the % o.m.s. has increased. This factor, as indicated in an earlier paragraph, is dependent on the proportion of bases present. It seems likely that *S. distincta* and *S. fossarum* occur on soils with a low or moderate % o.m.s. only when a certain proportion of bases is present. Where the proportion of bases is very low *S. scotti* is the dominant species,

even though the % o.m.s. be very low also. Typically, such conditions are found in sandy-bottomed heathland localities, e.g. Little Sea, Studland (Diver and others); in the present area they are found in Gill Head Reservoir (o.m.s. 12%) which has a stiff clay bottom supporting an abundant growth of *Juncus fluitans*. Pearsall (1920, p. 194) has shown that this plant grows on soils which are poor in bases with either a very high or very low % o.m.s.

The boundaries between the territories of species, particularly *S. scotti* and *S. castanea*, are often quite sharp. Thus the two stations in Wray Mires Fishpond 1 were barely 1 m. apart, one in the middle, the other at the edge, of a thick bed of emergent vegetation. *S. scotti* is always more numerous than *S. castanea*.

In the tarns in Table 6 there is a different succession of species. *Sigara scotti*, *S. fossarum* or *S. distincta* are found in the less advanced areas of the tarn. In areas with higher % o.m.s. they are replaced by *Cymatia bonsdorffi* and in the thickest reed-beds *Sigara linnei* is the dominant form; *S. castanea* is found only in quite insignificant numbers. Another species, *S. praeusta*, is commonly found but its relation to the others is still obscure.

In geological and botanical features these are similar to the tarns already considered. The only apparent difference is that the present tarns receive organic matter from some external source; thus Rather Heath 1, Slew, Rose Castle, Robinson and Lost are surrounded by trees; Rather Heath 6 and New are sufficiently near trees to receive a large number of dead leaves every autumn; and Podnet and Little Ludderburn are recently dammed peat mosses each containing a number of drowned birches. Rather Heath 6 and Lindeth are fouled by poultry and High Man is fouled by ducks. Kjeldahl analyses show that the mud of these tarns has a relatively low carbon/nitrogen ratio (12·3 to 16·2, average 14·1) but this is not significantly lower than that of some of the localities where *S. fossarum* and *S. distincta* are found.

Four tarns have been omitted from the tables. Two of these resemble the rest and have a high o.m.s. (37 and 60%), but they are inhabited, one by *S. striata* alone, the other by *S. striata* and *S. falleni*, both species characteristic of habitats where the % o.m.s. is low. The remaining two are peculiar; both are old quarry workings with no inlet or outflow, 6–8 ft. of water and a vast quantity of dead leaves. *S. sahlbergi* is the only species found in them.

(3) *Pools.*

Pools are abundant all over the Lake District: 69 are considered in this paper. They may be classified into high pools and low pools, for it is found that the two have quite distinct associations of Corixid species. It will be convenient to use the Corixid fauna as the criterion distinguishing the two rather than to assign a given altitude as a rigid boundary between them.

Low pools. (Pl. 1, phot. 3). The highest is 450 m. above sea-level. Though most are quite small, some cover an area of several thousand square metres, but the depth seldom exceeds 1 m. The commonest plant is *Sphagnum*, but others such as *Menyanthes trifoliata*, *Juncus fluitans*, *Utricularia* sp., *Potamogeton natans* and *Carices* are sometimes found as well. The *p*H of the water ranges from 4·5 to 6·5. Analysis of seven bottom samples showed an organic content ranging from 42 to 82% with an average of 75%. The most intense colour of the water was only 15 units.

There are 35 pools altogether, and the following is a list of species of Corixid recorded, with the number of pools in which each one was found:

S. castanea	(24)	*C. geoffroyi*	(2)
S. scotti	(17)	*S. linnei*	(2)
S. praeusta	(5)	*S. striata*	(1)
S. nigrolineata	(4)	*S. distincta*	(1)
S. sahlbergi	(3)	*S. limitata*	(1)
S. venusta	(3)	*S. semistriata*	(1)
S. hieroglyphica	(2)	*S. fossarum*	(1)

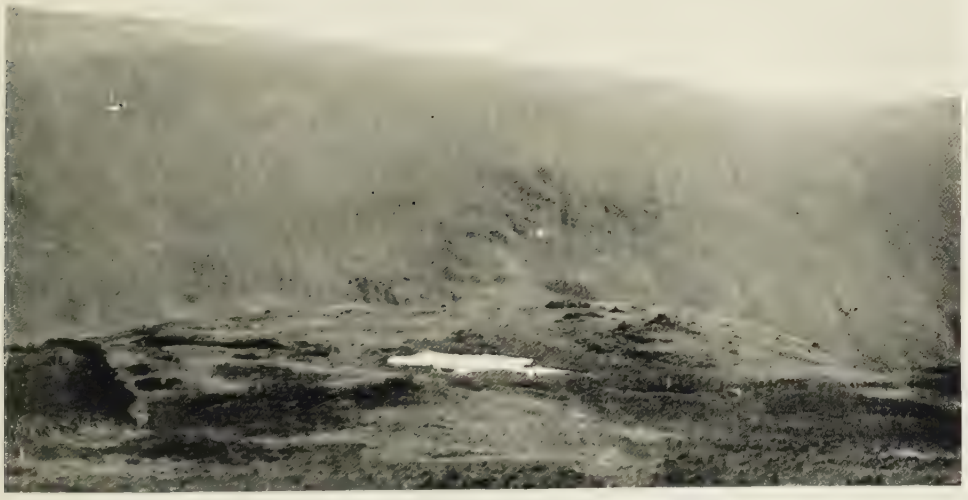
S. castanea was dominant in 14, *S. scotti* in 12, and in two pools both species were equally abundant: no other species was found in significant numbers in any of these 28 localities. As in tarns, *S. scotti* occurs where vegetation is sparse or absent, *S. castanea* where vegetation is dense. The occurrence of these two species and no others in this environment with a high % o.m.s. confirms conclusions drawn from the study of tarns.

In the remaining seven low pools, *S. nigrolineata* is dominant in three and *S. praeusta* in two. Both these species fly readily from the sorting dish which suggests an explanation of their distribution; for all the pools are small and shallow and are probably temporary, though only one has actually been seen to dry up. *S. venusta* is dominant in two localities which differ somewhat from the rest. They are shallow quarry excavations with a depth of little more than 40 cm. of water and the bottom is covered with slates on which grows an algal felt.

High pools. (Pl. 2, phot. 4). The lowest is 400 m. (1300 ft.), the highest 800 m. (2700 ft.), and the majority about 600 m. (2000 ft.) above sea-level. In extent they range from two to two or three hundred square metres, and in depth from a few centimetres to about one metre. The bottom is of peat and has a high % o.m.s. Analysis of samples from ten pools showed an organic content ranging from 53 to 91% with an average of 80%. The carbon nitrogen ratio of four samples ranged from 17·0 to 20·8. The water is seldom highly coloured and the number of units varies between 0 and 200; the *p*H ranges from 4·0 to 5·0, but is usually between 4·1 and 4·3. There are all stages between pools with no vegetation at all and pools completely overgrown with plants, such as *Sphagnum*, *Hypnum fluitans* and green algae.

Corixids are usually present and, though they are not abundant when compared with localities at lower altitudes, it is nearly always possible to collect between ten and twenty individuals. There are 34 pools, and the follow-

Phot. 3. Green Pool. *Sigara scotti* occurs in the open on the right, *S. castanea* in the *Carex* beds on the left.



Phot. 4. Seat Sandal. Habitat of *Corixa wollastoni*.

ing is a list of the species of Corixid together with the number of pools in which each was found:

S. wollastoni	(29)	*S. venusta*	(5)
S. nigrolineata	(27)	*S. castanea*	(2)
S. hieroglyphica	(12)	*S. scotti*	(1)
S. carinata	(8)	*S. praeusta*	(1)
C. geoffroyi	(5)		

in 32 out of the 34 *S. wollastoni* and *S. nigrolineata* or both were the only species which occurred in significant numbers and the proportions in which they were found were:

S. wollastoni %	Number of localities	*S. nigrolineata* %
0–10	10	90–100
10–20	1	80–90
20–30	3	70–80
30–40	1	60–70
40–50	1	50–60
50–60	1	40–50
60–70	3	30–40
70–80	2	20–30
80–90	1	10–20
90–100	9	0–10

The distribution of *S. wollastoni* and *S. nigrolineata* is evidently not random, but it is hard to make out what factors are concerned. Both species occur in pools with no vegetation and in pools with thick vegetation, so this factor, important in low pools, is not significant. Furthermore, it is unlikely that the nature of the soil or the water is important, for on six occasions it was found that of two pools lying close together in the same drainage area one was dominated by *S. wollastoni*, the other by *S. nigrolineata*. In five out of the six cases, however, the pool containing *S. nigrolineata* was distinctly smaller or shallower than the one inhabited by *S. wollastoni*. Further, isolated pools with *S. nigrolineata* tended to be smaller or were located in smaller drainage areas and this, linked with the observation that *S. nigrolineata* takes wing from a sorting dish more readily than *S. wollastoni*, suggests that these pools have dried up, and, being recently filled, are populated by the more active colonizer of the two species. It is hoped to investigate this suggestion by studying the invasion of artificially made pools.

In the remaining two pools *S. carinata* was dominant, and both were among the largest in the whole series. In one of them separate collections were made from the middle (depth about 0·5 m.) and from the edge. The catches were:

Middle	*S. carinata*	14	*S. wollastoni*	2	*S. nigrolineata*	1
Edge	*S. nigrolineata*	20	*S. carinata*	8	*S. wollastoni*	4

Both *S. carinata* and *S. wollastoni* are confined to the north of the British Isles, and may perhaps belong to the Alpine relict fauna. *S. nigrolineata* is common and widely distributed.

5. Acknowledgements

I desire to express my best thanks to Prof. G. Evelyn Hutchinson for many helpful suggestions and advice; to my colleagues at Wray Castle whose special knowledge has always been put freely at my disposal; to the landowners who have given me leave to collect on their property; to Dr F. H. A. Marshall, F.R.S., Mr J. T. Saunders, and Dr E. B. Worthington, who have kindly read and criticized the manuscript; and to Dr W. H. Pearsall, who has guided the work both in the field and in the laboratory, and who has been ready with a helpful suggestion at every difficult juncture.

6. Summary

1. The percentage of organic matter in a subaquatic soil has been shown by Pearsall (1920, 1921) to be an important factor in the distribution of certain species of plant. As the percentage of organic matter increases there is a succession of plant species. Different successions are found at different rates of increase of the percentage of organic matter.

2. The present investigation, carried out in the central and southern parts of the English Lake District, describes a similar relation between the soil and certain species of Corixidae.

3. Where the rate of increase of the percentage of organic matter in a soil is rapid there is the following succession of Corixidae:

$$\textit{Micronecta poweri} \rightarrow \textit{Sigara striata} \rightarrow \left\{ \begin{matrix} \textit{Sigara distincta} \\ \textit{Sigara fossarum} \end{matrix} \right\} \rightarrow \textit{Sigara scotti} \rightarrow \textit{Sigara castanea}.$$

4. For the succession where the rate of increase of the percentage of organic matter in the soil is slow the evidence is scanty. *Sigara linnei* and *Sigara sahlbergi* appear to be the last two species in the succession.

5. In 11 tarns, however, there was a succession:

$$\textit{Sigara scotti} \rightarrow \textit{Cymatia bonsdorffi} \rightarrow \textit{Sigara linnei}.$$

A fourth species *S. praeusta* is associated, but its relation to the others remains obscure. These tarns appear to differ from the rest in that they receive organic matter from an external source.

6. In localities above about 450 m. there is a quite distinct association of species. *Sigara wollastoni*, *Sigara nigrolineata* and, in two cases out of 34, *Sigara carinata* were dominant.

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THE ROOK (*CORVUS FRUGILEGUS*) POPULATION OF NORTH-WEST DENBIGHSHIRE

By M. MITCHELL

A PRIMARY survey of the area was made during the winters of 1934–35 and 1935–36. The actual census of nests was taken between 15 and 28 April 1936.

1. *The area.*

This consists of 112·75 sq. miles. It is defined on the north by the coast from the river Conway to the river Clwyd; on the east and south, to Llanfairtalhairn by the river Elwy, and from Llanfairtalhairn to the bridge over the Conway at Llanrwst by the Abergele-Llanrwst road; on the west the area is bounded by the river Conway. It varies in character, rising from sea-level to a height of 1298 ft., but may very roughly be divided into three regions: the coast, the river valleys and a stretch of moorland, much of which is 1000 ft. or more above sea-level.

Geologically the area is made up largely of limestone and shales. While lying for the most part in Denbighshire, very small regions of both Flint and Caernarvonshire are included in the area taken.

2. *Possible errors.*

(*a*) The birds may not have finished building by 28 April, but this is unlikely. (*b*) Nests may have been destroyed. (*c*) Mistakes in actual counting. This seems the most likely source of error though mistakes might tend to equalize. Where possible counts were checked by an independent helper.

3. *Results.*

Total area 112·75 sq. miles	Rooks per acre of cereals 1·84
Total nests 1571	Rooks per acre of roots 0·36
Nests per square mile 13·93	Rooks per acre of total arable land 4·52
Nests per square mile of agricultural land 18·7	Acres of agricultural land per nest 34·09

These figures are approximate, having been extracted in parishes, while the boundaries taken do not coincide exactly with the parish boundaries.

4. *Discussion.*

For the purpose of the census all sites exceeding a distance of approximately a quarter of a mile from one another have been termed rookeries.

Suggested factors influencing distribution.

(*a*) *Water.* 75% of the rookeries were within 250 yd. of a water supply of some sort.

(*b*) *Buildings.* 75% of the rookeries were within 200 yd. of buildings, although in several cases the rookery antedates the buildings.

(*c*) *Altitude.* No rookeries occur above 600 ft. Approximately one-third of the area is more than 600 ft. above sea-level.

(*d*) *Trees.* Elm, sycamore, oak, beech and pine are the species used, all extensively, though there appear to be more nests in elms than in any of the other trees.

(*e*) *Competition.* At the higher altitudes the rook appears to be replaced largely by the carrion crow (*Corvus c. corone* L.).

(*f*) *Distance apart of rookeries.* It is not the case in this district, as is suggested by Marples (**1**) working in the Wirral Peninsula, that rookeries tend to be spaced about a mile apart.

5. *Summary.*

Density of nests 13·93 per sq. mile. Preference seems to be shown for a site near water, although evidence on this point is not conclusive. Altitude appears to be a governing factor, there being no nests above a height of 600 ft. above sea-level.

6. Acknowledgements and thanks are due to the Statistical Branch of the Ministry of Agriculture and Fisheries; to the Borough Surveyor of Colwyn Bay; and to the many landowners who have made the taking of this census possible.

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THE FIELD MICE OF ICELAND

By PATRICIA LUPTON and URSULA WYKES

(*With* 1 *Map in the Text*)

1. Introduction

While we were planning an ecological expedition to Iceland in 1935, Mr Charles Elton suggested that a collection of Icelandic field mice should be made in order to compare them and their parasites with the species occurring in England, the Hebrides and Scandinavia, which have been the subject of surveys during recent years (Elton *et al.* 1931; Elton, 1934, 1936; Hora, 1934).

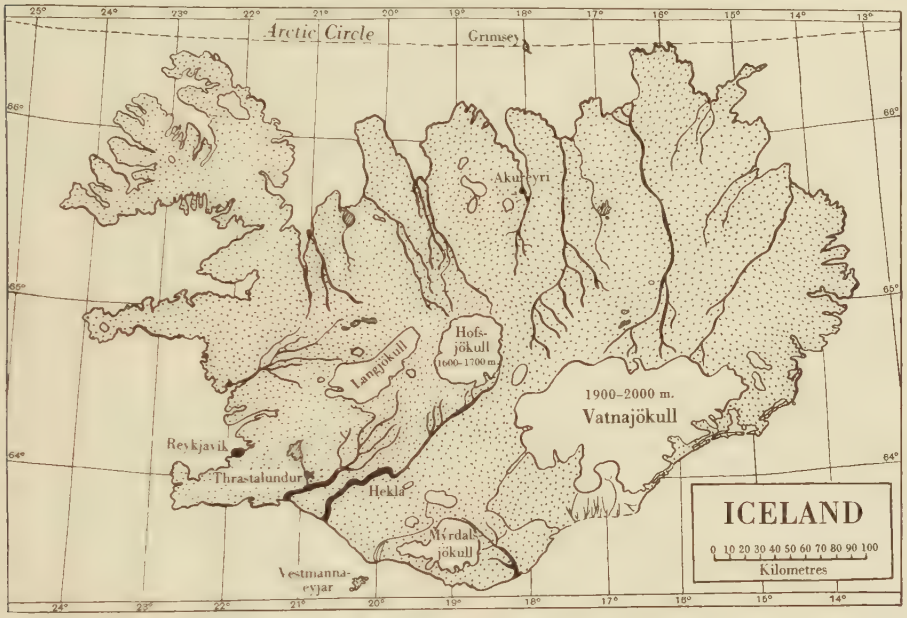
Although *Apodemus* is one of the few mammals indigenous to Iceland, very few references to it can be found in any scientific literature. Pennant (1792) mentioned that mice were plentiful in Iceland in the woods of Husafels. G. S. Miller (1912) in his catalogue of the mammals of western Europe includes under *Apodemus sylvaticus sylvaticus* six specimens from Iceland which are now in the U.S. National Museum. Mice are occasionally mentioned in Saga and travel literature, for example in the Floamanna and Biskopa Sagas which were composed in the latter half of the thirteenth century. The following passages from the Biskopa Saga indicate that, even at that time, mice were occasionally so plentiful as to be regarded as a plague:

> I, 194. There was such a plague of mice [in a small cottage] that she could hardly stay there.
>
> I, 293. Mice destroyed the corn and crops, and the ground in all parts there was hollow and full of mice [on an island called Videy].

Rats were distinguished from mice as *mýss valskar*, that is, foreign mice. Eggert Olafsen, himself an Icelander from the north-west coast, & Povelsen (1805) in their "Travels in Iceland" give the following account which seems to us so delightful as to be worthy of full quotation:

> There is but a small number of mice in Iceland, and the white mouse of the woods (*Mus sylvaticus*) appears to be only a variety of a domestic mouse. The instinct of this little animal induces it to collect a quantity of grain for its winter provender; and its magazines may be frequently discovered in the woods and outskirts. We are assured, that these mice undertake long journies, and even cross rivers, on which occasion they have the sagacity to pass the water in a diagonal line: they use pieces of dry cow-dung for rafts, which they load with grain on their return. The number attached to one of these rafts is from four to ten, and each of them assists in launching it. It is also curious, that they swim on each side, and their faces are opposite, while their tails serve for rudders. These voyages are not always successful, for sometimes their boats sink, when they save themselves by swimming with wonderful ingenuity. These curious circumstances were detailed to us by persons of credit, who had had ocular demonstration of the fact.

These references to the abundance of mice in early times discredit the opinion held by Hooker (1813) that "The few rats and mice, that are said to exist here, are brought by ships from other countries". The systematic position of the Icelandic mice will be discussed in a later section.



Map of Iceland showing location of Thrastalundur. Ice-caps white, lakes cross-hatched.

2. METHODS OF SURVEY

Birch-scrub (*Betula nana*), which is very common in certain localities in Iceland, seemed to provide the most probable habitat and for this reason we chose the district around Thrastalundur, Sogsbru, for our trapping activities. Thrastalundur lies on the eastern bank of the river Sog, some 70 km. east-south-east of Reykjavik, and at a height of 14 m. This region is composed chiefly of *Apalhraun* or block lava and is therefore extremely hillocky. It is colonized by *Betula nana*, reaching an average height of 60 cm., *Salix lanata*, *Cassiope hypnoides* and various species of grasses. The total area of scrub is approximately 2 sq. km. and covers part of the lava field of Hekla.

The trapping was done during the first week in August, by which time the short Iceland summer was already nearly over and night and day could be definitely distinguished. Break-back traps were used and each night 50–100 were set in groups of 5, 10, or 15 in different areas of scrub. They were placed as far as possible near mouse runs but these were often not very obvious and the holes were hidden in the cavities below blocks of lava. The traps were baited with cheese, and oats sprinkled round them. We visited the traps morning and evening and put the mice caught into separate canvas bags. We found mice

caught in the traps only in the morning which indicates that their habits are mainly nocturnal even during the summer months. The average catch of mice was not large, varying between one and ten a night, but the weather was so consistently wet that this was not surprising. The majority of mice were dead when found. Those which were still alive were killed with chloroform. Unfortunately no record was kept of the mice which were killed in this way, so that it is not possible to say whether they produced a higher percentage of parasites.

The fur of each mouse was examined carefully for ectoparasites which were preserved in alcohol. The skin was then removed, treated with arsenic-borax powder and preserved as a flat or "cased" specimen. The skins and skulls have been numbered B.A.P. 46 to 76 in accordance with the series of specimens of *Apodemus* sp. in the possession of the Bureau of Animal Population at Oxford, where the collection is provisionally deposited.

3. Measurements

Thirty-one mice were caught, of which 24 were males and 7 females. The body length, tail length, and total weight of each individual are given in Table 1. The weights of females may be subject to an error due to embryo weights not having been recorded. The parasites include 11 species of mites (Acarina) and one flea (Aphaniptera). For their distribution on different individuals reference should be made to the table.

4. Parasites

The most interesting point which emerges from a comparison of the parasites of the Icelandic mice with those of Continental and British species concerns the fleas. It appears that the Icelandic species is *Ctenophalmus agyrtes agyrtes* (Heller). This subspecies is widely distributed on the Continent, having been found in Norway, Germany, Austria and Switzerland. Another subspecies, *C. agyrtes* var. *celticus*, occurs in Great Britain and Brittany and has been found elsewhere in France. Since the fleas on these Icelandic mice belong exclusively to the subspecies *C. agyrtes agyrtes* it would seem that the mice must have been derived originally from the Scandinavian stock rather than that of Great Britain or its islands.

5. Status

The status of *Apodemus islandicus* has not been finally ascertained, and a full discussion will not be attempted here, since the Zoological Museum at Copenhagen will be publishing soon a report on the systematic position of the species, partly based on the materials loaned to the Museum by us. The general appearance of this form is, however, against it being simply an ordinary European wood mouse that has recently been transported accidentally to

Iceland. In its large size and rather brilliant coloration, the form resembles more *A. hirtensis* of St Kilda, and it may well be that it has been isolated upon Iceland for a very long time.

Table 1. *Measurements of mice and distribution of their parasites, Thrastalundur, 1–6 August* 1935

No. of mouse	Sex	Weight (g.)	Tail length (cm.)	Body length (cm.)	Parasites: Acarina: Tyroglyphidae	*Myobia musculi* Schrank	*Myonyssus gigas* Oudms	*Nothrus sylvestris* Nic.	*Nothrus palustris* Koch	*Pergamasus crassipes* L.	*Asca affinis* Oudms (deutonymph)	*Eugamasus furcatus* Can	*Haemogamasus michaeli* Oudms	*Eulaelaps stabularis* Koch	Aphaniptera: *Laelaps festinus* Koch	*Ctenophthalmus agyrtes agyrtes* ♀ Heller	*Ctenophthalmus agyrtes agyrtes* ♂ Heller
1	♂	17·6	7·9	9·1	—	—	—	—	—	—	—	—	2	4	8	—	—
2	♂	23·3	8·9	10·2	—	—	—	—	—	—	—	—	—	—	5	1	1
3	♂	35·17	9·8	9·2	—	—	—	—	—	—	—	—	—	1	4	6	5
4	♂	24·74	8·0	10·5	—	—	—	—	—	—	—	—	—	1	18	—	—
5	♂	30·20	10·2	10·8	—	—	—	—	—	—	—	—	1	—	2	—	—
6	♂	23·7	9·7	9·7	—	—	—	—	—	—	—	—	—	—	1	—	—
7	♂	22·9	8·7	10·6	—	—	—	—	—	—	—	—	1	—	17	—	—
8	♂	32·0	10·2	10·8	—	—	1	—	—	—	—	—	—	—	4	—	—
9	♂	35·0	10·1	10·5	—	—	—	—	—	—	—	—	—	—	14	1	1
10	♂	18·18	8·5	8·6	—	—	—	—	—	—	—	—	—	—	28	—	1
11	♂	36·1	9·0	11·2	—	5	—	1	—	—	—	1	—	—	19	3	—
12	♂	18·72	7·9	9·0	1	—	—	—	—	—	—	1	—	—	1	—	—
13	♂	18·7	9·6	9·2	—	—	—	—	—	—	—	—	—	—	14	3	—
14	♂	23·4	8·6	10·3	—	—	—	—	—	—	—	—	2	—	6	—	—
15	♂	20·1	8·9	8·5	—	—	—	—	—	—	—	—	—	4	2	—	—
16	♂	9·9	6·1	7·6	—	1	—	—	—	—	—	—	—	—	8	—	—
17	♂	26·0	8·6	9·4	—	—	—	—	—	—	—	—	5	5	20	2	1
18	♂	20·6	7·9	9·5	—	—	—	—	—	—	—	—	—	—	21	—	—
19	♂	19·7	8·1	9·1	—	—	—	—	—	—	—	—	—	4	9	3	3
20	♂	28·0	9·2	11·1	—	—	—	1	—	—	—	—	1	2	10	1	—
21	♂	21·8	8·6	10·1	—	—	—	—	—	1	—	—	—	—	22	2	4
22	♂	9·2	5·4	7·1	—	—	—	—	1	—	—	1	—	—	16	—	—
23	♂	9·3	4·5	7·0	—	—	—	—	—	—	—	—	—	5	8	—	—
24	♂	20·4	7·8	9·4	—	—	—	—	—	—	—	—	—	—	6	—	—
25	♂	33·0	9·6	10·7	—	—	—	—	—	—	—	8	—	2	27	5	6
26	♂	34·4	9·2	10·8	—	—	—	—	—	1	1	—	—	—	35	2	2
27	♂	17·1	7·9	8·3	—	—	—	—	—	—	—	—	—	—	18	—	—
28	♂	28·1	broken 4·9	10·3	—	—	—	—	—	—	—	—	3	4	17	2	—
29	♂	27·1	8·6	9·3	—	—	—	—	—	—	—	1	—	4	11	—	—
30	?	9·4	6·2	6·5	—	—	—	—	—	—	—	1	—	1	20	—	—
31	?	10·2	7·5	6·7	—	—	—	—	—	—	—	3	—	—	—	—	—

6. Acknowledgements

First and foremost we would like to thank Mr Charles Elton for his continual help and interest. We are much indebted also to Mr F. J. Cox and Mrs M. Hughes who undertook for us the identification of the fleas and mites respectively. The references to Saga literature were supplied by Prof. E. V. Gordon to whom we are very grateful.

7. Summary

1. A collection of Icelandic field mice was made in order to compare them and their parasites with the species occurring in Great Britain and Scandinavia.

2. The sex, weight, body length and tail length and ectoparasites of each individual were noted. The skulls and skins were preserved and are provisionally deposited in the Bureau of Animal Population at Oxford.

3. The subspecies of Aphaniptera found on the Icelandic mice, *Ctenophalmus agyrtes* var. *agyrtes* is widely distributed on the Continent and in Scandinavia but differs from the typical British species, *C. agyrtes* var. *celticus*. This suggests that the mice of Iceland were originally derived from the Scandinavian rather than the British stock.

4. The systematic position of *Apodemus islandicus* is being investigated by the Zoological Museum, Copenhagen, partly on the basis of this material.

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NOTES ON THE ANIMAL ECOLOGY OF BEAR ISLAND

By G. C. L. BERTRAM and DAVID LACK

(*With Plates* 3 *and* 4, *and* 1 *map*)

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PART I. GENERAL DESCRIPTION

1. Introduction

In 1921 Summerhayes & Elton (**28**) visited Bear Island, and thus started a series of investigations by British expeditions on the ecology of Arctic regions, followed up in Spitsbergen by Summerhayes & Elton (**29**), in West Greenland by Longstaff (**23**), in Central Iceland by Anderson & Falk (**11**) and on Akpatok

(Ungava Bay) by Davis (**17**). Reference should also be made to later work in East Greenland by Madsen (**24**) and Jørgensen (**21**). The present paper may be regarded as in the same series, and describes our work on Bear Island between 20 June and 10 August 1932.

The collections have been presented to the British Museum (Natural History), and a duplicate collection of insects to the Hope Department of Entomology, Oxford University.

2. Topography and geology

The general account of the present expedition (**3**) includes a description of the island. Horn & Orvin (**20**) give a detailed account of the topography and geology, and Summerhayes & Elton (**28**) of the botanical habitats. Hence only a brief description is given here.

Bear Island (see map, Fig. 1) in the Barents Sea in Lat. 74° N., and Long. 19° E., is one of the most isolated islands in the Arctic, the nearest land being Spitsbergen, 120 miles to the north, while Norway is 240 miles to the south. It is some 12 miles from north to south and 9 from east to west. Geographically it can be divided into three main regions. The northern half of the island is a plateau at about 100 ft. above sea-level, flat in the west, gently undulating in the east, with a central rather higher area, the Steinflya. This region is covered with a network of shallow lakes (Pl. 3, phot. 1). The second region, in the east, is Mount Misery, a plateau mountain with three peaks, the highest about 1770 ft. The third region is the southern mountains, the Antarctic Range and several other peaks, all rather lower than Mount Misery, and in many places terminating seaward in steep cliffs. The highest of these has a sheer drop of 1400 ft. This southern region has only a few lakes.

The oldest geological formation is the Hekla Hoek, found in the southern dolomite cliffs and across Mount Misery. Unconformably on these are Upper Devonian strata followed by the Culm. These are chiefly sandstones, with a few coal seams, and come to the surface over much of the north and east of the northern plateau. Middle and Upper Carboniferous limestones occur in the southern region and also in the west of the northern plateau, and Triassic sandstone occurs on the peaks of Mount Misery. In general the limestones make a fairly smooth walking surface, but in the sandstone areas the loose boulders varying from a few inches to several feet across make walking difficult (Pl. 3, phot. 2). In some places these boulders encircle clay centres forming polygons.

3. Climate

Considering its high latitude, Bear Island has a comparatively equable maritime climate. Horn & Orvin (**20**) give the average monthly temperatures as January, −9·4; February, −11·2; March, −11·0; April, −7·6; May, −2·3; June, +1·7; July, +4·2; August, +3·6; September, +1·9; October, −1·7; November, −6·3; December, −7·5° C.

A branch of the Gulf Stream flows along the west coast, but a cold current from the north flows down the east coast. As a result, the island is covered with thick fog almost continuously throughout the summer. For example, during our stay of 52 days only five were clear and sunny, and for an aggregate of

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Fig. 1. Map of Bear Island.

about 21 days visibility was limited to 30 yd. Hence the climate is extremely humid.

Drift ice has been recorded round the island in every month, especially between February and May, but it is rare between May and September. The highest point, below 1800 ft., is not sufficient to induce abundant snowfall, so

that areas may sometimes remain snow-free in late autumn and winter. The ground is permanently frozen below about 0·75 m. (**20**, p. 12), so causing the run-off of water to be extremely rapid. The ground water used by plants can therefore contain only extremely small quantities of mineral salts.

The midnight sun lasts from 30 April to 13 August.

4. Flora

The flora of Bear Island is rather poor compared with that of Spitsbergen to the north (**26**, **28**, **29**). Bear Island possesses only some 53 species of Phanerogams, Spitsbergen about 127. This difference is correlated with the very different climatic conditions in some parts of Spitsbergen, where, particularly at the heads of the fjords, bright sun and high summer temperatures are recorded. Summerhayes & Elton have divided Svalbard (the modern Norwegian name for Spitsbergen and Bear Island) into four botanical zones; and although Bear Island is the most southerly part of Svalbard, it is placed in the most barren zone, characterized by the absence of *Dryas*, *Cassiope* and *Empetrum*. In some respects, however, Bear Island is more akin to the richer zones, and it possesses two species of Phanerogams (*Hippuris vulgaris* and *Rhododendron lapponicum*) and several more southern mosses which have not been recorded from Spitsbergen.

Summerhayes & Elton (**28**) have classified the plant communities, and the following summary is based primarily on their account. Fjaeldmark occupies most of the dryer parts of the island. This very open community consists mainly of Phanerogams; chiefly scattered individual plants, with a fair proportion of mosses and lichens. *Saxifraga oppositifolia* and *Salix polaris* tend to be the dominants. Many areas, particularly in the sandstone boulder region, are almost devoid of plants. Especially in sheltered places on the limestone of the northern plateau, a closed community, Herb Mat, is found, but the areas it occupies are extremely circumscribed. A closed moss vegetation (in our collections we did not distinguish between Summerhayes & Elton's Moss Heath and Moss Mat) tends to occur in damper, more sheltered areas than the Herb Mat. Here mosses predominate, and lichens are numerous.

Some of these areas tend to dry up later in the summer, being thus distinguished from Summerhayes & Elton's Wet Tundra, which remains damp. The most distinct division of the last is the closed vegetation consisting almost entirely of mosses which surrounds many of the lakes, and sometimes the streams, particularly in limestone areas. This community is often submerged for considerable periods after the snow melt.

The abundance of mosses and lichens on Bear Island is probably correlated with the almost continual damp fogs in summer, and is in contrast with the comparative scarcity of these plants in dry, sunny parts of the Arctic.

Though the above plant communities can be defined, it should be stressed that in practice they are not usually clear-cut divisions. Furthermore, a plant

succession, when it occurs at all, would seem to proceed extremely slowly in the unsatisfactory conditions provided for plant growth. As an example of how slowly plants colonize, in 1899 Lerner levelled some ground as a road between Sörhamna and Walrus Bay. Thirty-one years later that road was still clearly marked, and had been colonized by extremely few plants, mainly *Saxifraga oppositifolia*.

5. Manuring by sea birds

Where, as in the Arctic, the nitrogen supply in the soil is extremely low, any additions will have a most marked effect. Such additions are supplied locally by the sea birds, and since these birds feed at sea, the nitrogen which they deposit in droppings is a constant additive factor, and the faeces add appreciably to the actual bulk of the soil. The effects of bird manuring on the vegetation in Spitsbergen have been discussed in detail by Summerhayes & Elton (**29**) and Scholander (**27**).

On Bear Island the most marked effects occurred on ledges, and on slopes not so steep as to fail to retain the dung, below cliff colonies, especially of kittiwakes and guillemots. Here occurs the most luxuriant vegetation on the island, consisting almost exclusively of *Cochlearia*. On the unmanured cliff tops these plants were closely appressed to the ground and the leaves were typically less than 2 in. long. Below the kittiwake colonies growth was luxuriant, and the leaves up to a foot in length. On the damp cliff faces, manuring seemed also to assist the growth of *Enteromorpha*. On the other hand, too great manuring seemed to stultify the vegetation, as by some of the guillemot colonies and in the immediate neighbourhood of the more crowded kittiwake nests. It was also interesting to find at Tunheim a good growth of *Cochlearia* below what had, some 8 years before, been a miners' lavatory which opened directly over the cliff.

A second effect of manuring was the production of a closed Grass Mat. This would seem to be a divergence from the normal Herb Mat of Bear Island, and was found only in connexion with manuring in dry areas. It occurred as a rather narrow margin on the dry flat cliff top above glaucous gull colonies. The latter birds are in the habit of standing in numbers on the cliff top above their nests. There was also a much larger area round the huge glaucous gull colony at Cape Dunér (Pl. 4, phot. 3). "Skua hummocks" (**28**), found scattered in the fjaeldmark where arctic skuas perched or nested, were sometimes composed predominantly of Grass Mat.

In addition to these prominent effects, manuring on a smaller scale resulted in a general increase of the vegetation in certain areas. Thus the islet in Laksvatnet, where many arctic terns and eiders nested, had a richer vegetation than the neighbouring fjaeldmark, as had many of those "skua hummocks" which did not attain the state described above. Most of the scree slopes were almost devoid of vegetation, the chief exception being those beneath the inland colonies of puffin and little auk on Mount Misery. In some of these sloping

cliff areas a closed vegetation of mosses and *Cochlearia* had developed. Finally, certain of the lake margins were extensively resorted to by glaucous gulls and kittiwakes for bathing and resting, resulting in a richer development of the moss margin. In a few places this manuring had been so intense as to retard the growth of mosses.

6. Extent of the 1932 survey

Observations and collections of the fauna were extended to all the important land and fresh-water habitats, and during a stay of $7\frac{1}{2}$ weeks it was possible to work many samples of each type. Attention was concentrated on the Vertebrates and Arthropods, but among the latter the Tardigrades and the insect parasites of mammals and birds were omitted. Apart from the nesting sea birds, marine life was not studied.

Tunheim in the north-east was used as a base, from which journeys were made all over the island, though the north and east were naturally worked more frequently than the south and west. The present survey is the most complete yet made, for previous zoologists had visited only circumscribed areas and for short periods, most of such visitors being on their way to or from Spitsbergen. The most important previous visits were that of the Oxford University Expedition of 1921 (**28**) which stayed 10 days in June in the south, and that of Thor (**30**) who stayed about a week at the end of July 1928 at Tunheim.

The summer of 1932 came extremely late. The land did not become snow-free until a day or two before our arrival, and drift ice was said to have been round the island until 10 days previously. Consequently observations could be made from the beginning of summer, which assisted the completeness of the survey. However, it is quite possible that, especially considering the lateness of the summer, a number of insects did not emerge until after our departure on 10 August, or perhaps not at all in 1932. Thus no adult *Prosimulium ursinum* were captured though larvae and later pupae were not uncommon, and hence it is possible that other Diptera with less conspicuous larvae might have been overlooked in 1932.

A complete list of the Vertebrates and Arthropods known from the island is given as an Appendix. In addition to adding many new forms to the island list (for details of which see the papers on the special groups, References A), the 1932 collection included nearly all the Arthropods (omitting some doubtful forms) found by previous collectors, except in the case of the mites (Acarina). The last were missed presumably through inexperience in collecting, though hundreds of specimens of certain species were brought back. For the mites, Thor's list (**30**) has been primarily used.

The ordinary methods of collecting were used, a sucking tube being the most valuable instrument for the larger insects, and a simple modification of the Berlese funnel for the Collembola and mites living in vegetation.

Phot. 1. The northern, lake-covered area.

Phot. 2. Steinflya—the central stony desert, a region almost devoid of vegetation.

Part 2. Ecological distributions

7. The fresh waters

General notes

Owing to the small size of the island, none of the streams and rivers are large. They run fastest after the snow melt, and some of them dry up later in the summer. Apart from the larvae and pupae of *Prosimulium ursinum* and various Chironomidae, they contain almost no animal life.

Lakes and ponds are extremely numerous on the northern plateau, (Pl. 3, phot. 1) where they are all shallow (apparently none more than 21 ft. deep), and there are a few in the southern mountains, the most important being Ella Lake which is said to be 140 ft. deep. There are no brackish lakes nor any that can be considered of a relict type, such as occur in Spitsbergen.

The lakes fall into two main types. Those on the sandstone had an average *p*H of 6 (with little variation), their shores are usually devoid of vegetation and their bottoms consist of bare boulders. Those on the limestone had a *p*H of about 7·5 in the absence of sea bird manuring and marginal vegetation (which usually go together); but in the presence of these two the *p*H rose above 9, a high figure; the surrounding vegetation is typically a partially submerged closed moss bog, the bottom being usually covered by grey mud. Other lakes are intermediate between these two types, and thus a wide variety of conditions are represented. The extremes of *p*H were 5·6 in a sandstone lake, 9·6 in a manured limestone one.

On Bear Island, once the winter's ice has melted, the shallow fresh-water lakes rapidly tend to reach a temperature at which they are in radiative equilibrium with the heat received from the sun. However, as a result of the oceanic and atmospheric conditions in the neighbourhood, the air temperature over the island remains low, the average for July, the hottest month, being 4·2° C. Thus a peculiar state is reached in which the lakes are maintained at a temperature several degrees higher than that of the air. Of 43 readings in various lakes, the following are typical. On our arrival on 20 June nearly all the lakes still bore ice. As early as 26 June the temperature in Mosevatnet (a small lake in the north) was as high as 7·2° C. A small pond, measured 3 days later, was 1·5° C. at one end, while ice was still melting in another part. As early as 7 July a third had reached 9·5° C., and from now on most of those recorded were between 7 and 9° C. The larger lakes were slower to warm up, and were usually rather below this. As a check, the temperature was taken of the water in a deep pit (sunk in the coal mining days) which, being of small surface area, received proportionately little radiation. On 21 July the temperature here was only 1·5° C. It may be noted that the shallowness of most of the lakes (except Ella) and the frequent winds favour complete mixing of the waters and the absence of a temperature gradient. Summerhayes & Elton (**28**, p. 272) recorded temperatures in one Spitsbergen lake.

Collections of fresh-water animals were made in all the main types of lakes, the only omission being that, owing to lack of a boat, collections from Ella lake were limited to near the shore.

Lake fauna

(*a*) *Vertebrates*

The birds have been reported on in detail elsewhere (**4**). A number of ducks used the lakes, and waders and geese the lake and river margins, for resting and feeding when on migration. Omitting these, and also the uncommon breeding species, two species of duck, the long-tailed (*Clangula hyemalis*) and the eider (*Somateria mollissima borealis*) used the lake islets for breeding, but the eider was the only common species. The latter take their young to the sea when hatched, and Coward (**15**) states that the duck does not feed during incubation. The only common wader was the purple sandpiper (*Calidris m. maritima*) which fed chiefly on Chironomid fly larvae in the moss of the lake margins and probably at times on land insects. In June these birds were observed far out on the lakes picking through cracks in the fragmenting ice, presumably for Chironomid larvae, the only sizable animals in the plankton at that time. The red-throated diver (*Colymbus stellatus*) at times fed its young on the arctic char (*Salvelinus alpinus*), as did the two pairs of great northern diver (*C. immer*); but many of the lakes frequented by *C. stellatus* did not contain char, so that the birds fed at sea. Finally the arctic tern (*Sterna macrura*) also used the lake islets for nesting. These birds obtained most of their food at sea by diving, but they were also seen skimming Chironomid larvae and probably *Lepidurus arcticus* from the surface of the lakes, and occasionally hawked for adult Chironomidae in the air—three very different types of feeding. Hence although in some cases the lakes supplied a part of the food (possibly most or all for *Colymbus immer*), the birds chiefly frequented them for nesting on the islets, where they were safe from the arctic fox.

The arctic char (*Salvelinus alpinus*), the only species of fresh-water fish, occurred in many of the lakes, chiefly those connected with the streams and rivers. The fish apparently reach other lakes by temporary communications during the snow melt. On Bear Island, adults are found throughout the year, and in winter are caught in large numbers through holes in the ice. The stomachs examined contained nothing but large numbers of Chironomid larvae. For what little is known of the biology of this fish, see Dahl (**16**).

(*b*) *Arthropods*

As on land, the bulk of the fauna consisted of Arthropods. One water mite, *Sperchon lineatus*, was found on stones in the bottom of some of the lakes, and Thor (**30**) states that it is abundant in thick moss at the sides of the rivers.

The most conspicuous element in the insect fauna is the huge number of Chironomid fly larvae, which occur on stony and mud bottoms, in the thick

moss at the lake and stream sides and in the lake plankton. From a determination of the adults, 26 species of Chironomidae have been recorded from Bear Island (**6**), but not all of these have aquatic larvae. However, their life histories have not been worked out, so details cannot be given. Despite the large number of individuals which were collected, several species of Chironomidae were represented by only a few individuals and seemed very local (see Edwards (**6**) and Appendix 1). The only other group of Diptera were the Simulidae. The larvae of *Prosimulium ursinum* were found in several fast-running rivers and streams, but only in those which had come from lakes, presumably since only in these was there sufficient planktonic food. One species of caddis, *Apatania arctica* was found, the cases of sand and small stones being found on the rock and silt bottoms of the larger lakes (**7**).

Of the fresh-water Crustacea, which are very abundant in number of individuals, 15 species have been recorded, of which 6 were common. The occurrence of the various species over the island is erratic. Thirteen species were collected in 1932, and in only 15% of the collections were more than three species taken together in any one lake or pond. The greatest number of species in any one pond was five, found only once. Attempts were made to correlate the specific distributions with environmental factors such as the *p*H, the nature of the bottom and the amount of sea-bird manuring, in most cases with little success. There seems to be no summer cycle of dominant species; but further details need not be recorded here, since they have been already published (**2**).

8. Other invertebrates

No fresh-water Mollusca or Planaria are known from Bear Island. Non-Arthropod groups were not collected in 1932, but some information on the Rotifers and Enchytraeid Oligochaetes may be obtained from Summerhayes' and Elton's account of the Island, with which the present paper is in some ways complementary.

9. Land fauna

(*a*) *Vertebrates*

Two mammals have been recorded, but the polar bear (*Thalarctos maritimus*) is only an occasional winter visitor. A number of arctic foxes (*Alopex lagopus*) were present. Ptarmigan (*Lagopus mutus hyperboreus*), one of the most usual summer foods of the arctic fox, were extremely scarce. One fox was seen capturing a puffin on the cliff edge, and probably much of their food was obtained from the sea-bird colonies. Most of the birds breeding by the fresh-water lakes nested on islets and so were inaccessible.

Apart from a few individuals of several species, none of which were proved to have bred in 1932 (**4**), the snow bunting (*Plectrophenax n. nivalis*) was the only Passerine bird. It was well distributed on the coast and inland where the rocks afforded crevices for nesting, but was absent from the upper parts of

Mount Misery, the Antarctic Mountains and almost the whole of the western part of the northern plateau, where the limestone did not afford crevices. Until the end of June, it fed mainly on vegetable matter, after this mainly on insects, capturing them on the wing on warmer days and searching for them among the boulders on colder ones. Another fruitful source was the snow patches, where numerous insects had fallen and remained in cold storage. Every available type of insect and spider of convenient size appeared to be taken. The only other land birds were a very few ptarmigan (*Lagopus mutus hyperboreus*), which feed on plants.

(*b*) *Arthropods*

The following table gives the typical habitat distributions of the commoner land Arthropods. (For complete list of species see Appendix 1.)

Table 1. *Characteristic habitat distribution of certain of the land Arthropods*

Group 1. *Under rocks, boulders and stones:*	
(N.B. The Trichoptera, Lepidoptera and Diptera were on the wing on warmer days.)	
Collembola	*Isotoma viridis*
Trichoptera	*Apatania arctica*
Lepidoptera	*Plutella maculipennis*
Diptera, Mycetophilidae 7 spp.	*Exechia frigida*
	Sciara spp.
Diptera, Chironomidae 26 spp.	*Procladius, Cricotopus, Spaniotoma, Chironomus, Tanytarsus,* etc.
Arachnida	*Coryphaeus holmgreni*
	Erigone tirolensis
Group 2 A. *In vegetation, moss and herb mat:*	
Collembola	See Table 2 and Appendix 1
Acarina	See Appendix 1
Group 2 B. *In herb mat (on the wing on warmer days):*	
Hymenoptera, Symphyta	*Amauronematus alberich*
	A. villosus
	Pristiphora frigida
Hymenoptera, Ichneumonidae	*Stenomacrus pedestris*
	Syndipnus beerensis
Diptera, Muscidae	*Limnophora megastoma*
Group 3. *On bird cliffs, under stones and in manured vegetation:*	
Collembola	*Achorutes viaticus*
Coleoptera, Staphylinidae	*Omalium septentrionis*
	Olophrum boreale
	Arpedium brachypterum
	(*Micralymma marinum* on cliff top but not in heavily manured areas)
Diptera, Mycetophilidae	*Boletina apicalis*
Diptera, Trichoceridae	*Trichocera lutea*
	T. maculipennis
Diptera, Cordyluridae	*Scatophaga nigripes*
Diptera, Helomyzidae	*Leria modesta*
	L. septentrionalis
Acarina	*Ameronothrus lineatus*

Note on Table 1

Table 1 is intended to give the typical distributions only. Thus all the animals in Group 1 occurred at times in the vegetation, and many of them on the less heavily manured parts of the bird cliffs. But since this has no special significance, except for *Isotoma viridis* and the larvae of

Mycetophilidae and *Plutella maculipennis* in vegetation, they are omitted from the other divisions. The species in group 2B were occasional elsewhere. Group 3 is intended to include only those species of the bird cliffs which were much commoner here than elsewhere on the island. Many of the Collembola and Acarina, some of the Chironomidae and Mycetophilidae, and particularly the spider *Coryphaeus holmgreni* occurred in the less heavily manured parts, as they did over most of the island. But of these only the spider was present in as great numbers as elsewhere, though it was absent from the most heavily manured areas. Of the species in group 3 a number were occasional, and some regular, in other habitats, as discussed later.

Notes on the abundance of the different forms were not included in Table 1. But an idea of their relative abundance can be obtained from Appendix 1 in which various notes are given and, for most of the insects, the number of individuals collected.

Group 1. *Rock and boulder fauna.*

The winged insects in this group occurred under boulders on the sunless days, but since nearly all the days were sunless, they must be regarded as typical members of this habitat. The Chironomidae were sometimes extremely abundant, particularly near to the lakes. The spider *Coryphaeus holmgreni* was very widely distributed, often living even in the Steinflya, the central stony desert, where there was almost no vegetation. It was seen taking *Isotoma viridis* and also adult Chironomidae, and from the spider's presence in many places where Collembola and mites were scarce or absent, it is clear that its main food was adult Chironomidae on the days when the latter were sheltering under stones—a somewhat variable food supply.

Quite a number of the Chironomidae and Mycetophilidae (**6**), the spider *Erigone tirolensis* and the two cliff Staphylinidae, *Olophrum boreale* and *Arpedium brachypterum* (for the two last, see Fauna of bird cliffs) were curiously local in their distribution. For example, of 460 spiders collected, all were *Coryphaeus holmgreni* except ten. These ten *Erigone tirolensis* came from under stones in only two localities: Laksvatnet in the north, and Walrus Bay in the south, though there were many other places apparently similar to these; see also Bristowe (**5**).

Group 2*A*. *Collembola and Acarina.*

The abundance of Collembola and Acarina was one of the most striking features of the Bear Island fauna. Presumably it is correlated with the relative abundance of mosses and lichens and the high humidity, in which respects Bear Island differed conspicuously from Hurry Inlet, East Greenland, where Collembola and Acarina were relatively much less common (**22**).

With the help of a Berlese funnel, the Collembolan fauna of 48 samples, which included all the main plant communities, was investigated, and the results are summarized in Table 2.

As can be seen from Table 2, most species of Collembola occurred in all the main habitats, except under bare stones, in the partially submerged Moss Bog and on the surface of the water. In general, the relatively dry Herb Mat supported very many fewer individuals than the damper Moss Heath and Moss Mat, Grass Mat (which was the dryest of all) being especially poor. But so far as the rather small number of samples enables one to judge, they were the

Table 2. *Distribution of the Collembola*

	Typical Herb Mat	Grass Mat	Moss Heath Moss Mat	Partially sub-merged Moss Bog	Tide line*	Glaucous gulls' nests	Bird cliffs	On water	Under stones
No. of samples	7	3	15	5	4	5	7	—	—
Onychiurus armatus	× ×	×	—	—	× × ×	× ×	×	—	—
Achorutes viaticus	×	×	× ×	× × ×	×	× ×	× × ×	—	—
Xenylla humicola	×	×	× ×	×	×	× ×	× ×	+	—
Tetracanthella wahlgreni	×	×	× ×	—	—	× ×	×	—	—
Folsomia quadrioculata	× × ×	×	× × ×	—	—	× ×	×	—	—
F. sexoculata	—	×	× ×	—	—	× ×	×	—	—
Isotoma viridis	×	×	×	—	×	×	×	—	+
Sminthurides malmgrenii	—	—	—	× ×	—	—	—	+	—

× indicates present in one-third or less of the samples examined, × × present in two-thirds or less, but more than one-third, and × × × present in more than two-thirds.

+ indicates recorded from this habitat, but no Berlese samples taken.

* The four samples on the tide line were at Evensenhamna, which was exceptionally rich in flotsam. Tide line samples from other parts of the island contained no life at all, except an occasional *Arpedium brachypterum* in the south.

same species in each of these habitats except that *Onychiurus armatus*, including var. *arcticus*, was not found in the closed Moss vegetation.

Mites were abundant wherever there were Collembola, particularly, like the Collembola, in closed Moss vegetation. Unfortunately, though hundreds of individuals were collected, too many species were apparently overlooked to make a table similar to that for the Collembola profitable. Thor (**30**) gives habitat notes on this group.

Group 2B. Winged insects of Herb Mat.

The two species of *Amauronematus* were widespread but never at all numerous. *Pristiphora frigida* was extremely local, being found only in Walrus Bay. The biology of these sawflies is unknown. One larva was found on *Salix polaris*, but died before pupating.

The two species of Ichneumonidae, and the fly *Limnophora megastoma*, emerged later in the summer and only on certain days, but were then extremely numerous; Roman (**10**) notes this as unusual for *Syndipnus*. Roman considers that *Syndipnus beerensis* probably parasitizes a sawfly and *Stenomacrus pedestris* a Mycetophilid fly. As adults these Ichneumonidae occurred chiefly in the flower heads. The latter were frequented when in season by many other Arthropods, including Chironomidae, most of the Diptera of the bird cliffs, the Staphylinid *Arpedium brachypterum* and also an occasional mite and Collembolan, all of which must therefore be included as temporary members of the Herb Mat.

Phot. 3. Grass mat, developed only on dry cliff tops near the nests of glaucous gulls (*Larus hyperboreus*) at Cape Dunér, West Coast.

Phot. 4. Small fraction of a guillemot (*Uria aalge* and *U. lomvia*) colony near the south end of the island.

Group 3. *Fauna of the bird cliffs.*

As before mentioned, only those species commoner on the bird cliffs than elsewhere are included in Group 3. Of these species, a few, such as *Omalium septentrionis* and the two species of *Leria*, were not found away from the bird cliffs (except that the two species of *Leria*, like other cliff forms such as *Boletina*, *Trichocera* and *Scatophaga*, at times visited the flower heads, particularly of *Sedum rhodiola* and *Saxifraga caespitosa*, on the cliff top). The other cliff Diptera were occasionally found some distance inland from the cliffs, but probably did not breed away from them. *Olophrum boreale* and *Arpedium brachypterum* each occurred sparsely in one inland and unmanured locality and the latter also on the tide line occasionally. *Achorutes viaticus* and *Amerongthrus lineatus*, though both frequent inland, were astoundingly abundant on the bird cliffs. Summerhayes & Elton (**28**, **29**), Madsen (**24**) and Jørgensen (**21**) record these two last, from coastal and/or manured areas.

Scatophaga and *Leria* are characteristic of manured habitats elsewhere, like *Cochlearia* among the plants. But the occurrence of the *Omalium*, *Olophrum*, *Arpedium* and *Trichocera* in manured areas on Bear Island seems analogous to that of the Grass Mat. Typically they are much more generally distributed, but on Bear Island conditions are presumably too severe except on the bird cliffs. It is of interest that *Olophrum boreale* and *Arpedium brachypterum* each occurred in one inland locality (the former by Laksvatnet and the latter at the north foot of Mount Misery) and that the specimens of the former were markedly smaller than those from the bird cliffs. The three species of Staphylinidae appeared to feed mainly on decaying matter (**7**), and their restriction to the bird cliffs may have been directly correlated through food supply with the general scarcity of decaying matter on the normal terrain of the high Arctic.

Micralymma marinum occurred only under stones in certain dry localities on the cliff top which received a small amount of manuring. It was not found inland or on the heavily manured bird cliffs.

As regards the fauna of manured areas away from the bird cliffs, in Grass Mat the Collembola and mites were similar to those of typical Herb Mat, but the individual total was very much smaller. Hymenoptera and *Limnophora megastoma* were absent from Grass Mat. Thus Grass Mat has much the poorest fauna of any vegetation on the island. The manured closed moss vegetation was similar to unmanured, except that round some of the most manured lake margins *Achorutes viaticus* was extremely abundant.

Fauna of birds' nests.

The Arthropods in all the main types of birds' nests were examined. In all cases except two, details have been omitted here since the animals were those typical of the materials of which the nest was composed or of the surrounding vegetation, and hence birds' nests do not greatly affect the Arthropod fauna. (The Collembola from glaucous gulls' nests are recorded in Table 2.) But one

eider's nest, out of many examined, contained five specimens of *Microprosopa frigida* (**6**), a species of Cordylurid Diptera which was not collected elsewhere. The one nest of a snow bunting examined contained a single *Enicmus minutus* and four large black Sminthurid springtails, probably *Sminthurinus niger*. (The nests of other species examined included starling, long-tailed duck, purple sandpiper, red-throated and great northern divers, arctic tern, arctic skua and kittiwake.)

(*c*) *Animal communities*

The above tabulation into four main habitats seems the most satisfactory for the Bear Island Arthropoda. Summerhayes & Elton (**28**) list the animals found in each plant community, but, as they remark, though each plant community has a fairly constant set of animal species associated with it, few of these animals are exclusive. This the 1932 survey bears out, and it arises because the plant communities as defined by the botanist are by no means necessarily significant as regards the factors limiting the animals. Hence the classification of the animal distributions in terms of such communities seems of doubtful value. A similar conclusion has been reached by Jørgensen (**21**) who, working on the Collembola and Acarina of East Greenland collected from many types of plant associations, classifies them into four communities based primarily on the degree of humidity. A classification based on the lower plants, on which the Collembola and mites depend, might be significant, for the lower plants also depend on the humidity, but not one based directly on the higher plants.

(*d*) *Temperature effects*

That the average air temperature for July, the hottest month, is only 4·2° C. has an important effect on the flying insects. Thus, although Chironomidae were extremely abundant, aerial swarms were seen only on a few of the warmest days. For the rest of the time, the Chironomidae were found chiefly under the boulders. It seems primarily because of this fact that the spider *Coryphaeus holmgreni* can be so widespread. The caddis, *Apatania arctica*, and the Mycetophilidae were also under the boulders on the less warm days.

The sawflies emerged in June and were active at lower temperatures than the other species of the Herb Mat. The two species of Ichneumonidae, and the fly *Limnophora megastoma* emerged only in July onwards and were active on extremely few days. In particular *Stenomacrus pedestris* was first recorded on 23 July, and was numerous on only 3 days between then and 10 August, a few individuals being out on 3 other days. Experiments could not be carried out on the lines adopted by Bertram (**12**) in Greenland in 1933, but from observation it seems probable that the two Ichneumons and *Limnophora megastoma* required an air temperature of at least 6° C. before they appeared. In the periods between the warm days, they retired into the Herb Mat; on one occasion they were seen appearing in swarms from a patch of *Salix polaris*

when the temperature rose. Presumably the number of sunny days in late summer on Bear Island very materially affects the number of matings which take place and of eggs laid.

As in the lakes the temperature in the vegetation and to a less marked extent under the boulders was usually higher than that of the air. Temperatures in the micro-habitats were measured roughly, with an ordinary Centigrade thermometer, no more precise means being available for systematic observations. In general it was found that on the typical foggy days with an air temperature of 3–5° C. the temperature in the vegetation was at least 2 or 3 degrees higher. This may perhaps be important for the Collembola and mites though the critical temperature for activity in the Bear Island forms is not known. It may also be noted that when the winged Diptera and Ichneumonidae retired, according to their kind, under boulders or into the vegetation, they moved into areas of more suitable temperature.

In most cases the temperatures in the micro-habitats on the manured bird cliffs were not significantly higher than those elsewhere. A marked exception was the moss nest of a glaucous gull, built on the remains of at least six previous nests, the whole structure being 50 in. in diameter and 18 in. deep. In this the temperature near the centre was 24·5° C., much the highest temperature recorded on Bear Island. The nest contained many Dipterous larvae (chiefly of *Leria*) and the increased temperature presumably accelerated their rate of development. But large nests of this type were rare, and so far as our rough measurements showed, decaying matter was not normally important in raising the temperature of the cliff micro-habitats.

PART 3. SOME GENERAL ASPECTS

10. Composition of the fauna

A full list of the known Bear Island Vertebrates and Arthropods is given in Appendix 1. As compared with the Palaearctic land mass to the south, Bear Island has far fewer species in every group. The fauna is also poorer than that of the warmer parts of Spitsbergen, but is much richer than, for instance, North East Land (**29**).

Among the Arthropods, notable absentees as compared with the Spitsbergen list are Neuroptera, Hemiptera, Curculionidae, Empidae, Syrphidae, Culicidae and large Lepidoptera. Further only five species of parasitic Hymenoptera have been recorded from Bear Island, but some ten other species from Spitsbergen. Two species of spiders occur on Bear Island, these and some nine others in Spitsbergen. Fifteen species of fresh-water Crustacea occur on Bear Island, 11 of these and 15 others in Spitsbergen. There is a similar paucity of Diptera on Bear Island as compared with Spitsbergen. In the great majority of cases the species in these groups which occur in Spitsbergen, but not on Bear Island, occur on the Palaearctic land mass to the south, and in Spitsbergen

are confined to the warmer parts, especially near the heads of the fjords. Presumably a climatic factor, probably temperature, is concerned in their absence from Bear Island.

These facts accord with the botanical data on which Summerhayes & Elton (**29**) put Bear Island in the most barren of the four floral zones into which they divided Spitsbergen. On the other hand, they noted certain resemblances to the more favourable zones 3 and 4, and this is borne out by the presence on Bear Island of the spiders *Coryphaeus holmgreni* and *Erigone tirolensis*, the sawflies *Pristiphora frigida* and *Amauronematus villosus*, the caddis *Apatania arctica* and the moth *Plutella*, which are recorded from Spitsbergen only in the warmer zones. (The *Plutella* is a different species.) Further a few species, notably all five species of Coleoptera, eight of Diptera (*Procladius crassinervis*, *Spaniotoma oxonianus*, *Chironomus psilopterus*, *Tanytarsus gracilentus*, *Cynomyia mortuorum*, *Leria modesta*, *Leria septentrionalis* and *Piophila vulgaris*), four of fresh-water Crustacea (*Daphnia longispina*, *Sida crystallina*, *Cyclops gigas* and *Cyclops viridis*), and the water mite *Sperchon lineatus*, are known from the Palaearctic land mass and Bear Island, but not from Spitsbergen. In certain cases (probably in most of the Diptera) the apparent absence of these from Spitsbergen is almost certainly due to lack of collecting, but some at least probably represent a small more southern element in the Bear Island fauna.

It is curious that the five species of Coleoptera found on Bear Island have not been recorded from Spitsbergen and that the four species known from Spitsbergen have not been found on Bear Island.

Of the Arthropoda common to Bear Island and Spitsbergen, nearly all the Collembola and mites, at least ten species of Diptera, both species of spider and the caddis *Apatania arctica* occur also in Greenland, and may be regarded as widely distributed Arctic forms. Three species of Diptera, the most interesting being *Simulium ursinum*, have been recorded from Bear Island and Greenland but not Spitsbergen. Apart from four species of Diptera, all of which Dr Edwards considers to be of doubtful validity, the sawfly *Amauronematus alberich* is the only species recorded only from Bear Island, and this last case may well be due to lack of collecting elsewhere.

Coming to Vertebrates, the one fish, the arctic char, is a widely distributed species. Of the mammals, both arctic fox and polar bear are circumpolar. Spitsbergen possesses these, and also the reindeer, absent from Bear Island. Of the 26 species of birds breeding (including doubtfully breeding) on Bear Island, 17 are common to Spitsbergen and the Palaearctic land mass. Six, namely herring gull, razorbill, common guillemot, and, of doubtful breeding species, starling, tufted duck and golden plover, breed in Norway and Bear Island, but not Spitsbergen. Two only, the grey phalarope and little auk, both circumpolar species, breed in Spitsbergen and Bear Island but not on the Palaearctic land mass. On the other hand, eight species typical of the most

northerly parts of the Arctic breed in Spitsbergen but not on Bear Island: pink-footed, barnacle and brent geese, king eider, knot, sanderling, Sabine's and ivory gulls. (In addition several other more widely distributed species breed in Spitsbergen and not on Bear Island.) One species, the great northern diver which breeds on Bear Island, also in Iceland, Greenland and Arctic America, has not as yet been recorded breeding either in Spitsbergen or Scandinavia, but may perhaps breed in the latter places as it has been observed there during the summer.

Hence the birds of Bear Island are definitely more southern in character than those of Spitsbergen, in marked contrast with the Arthropods, in which Spitsbergen, not Bear Island, possesses a larger southern element. This contrast results mainly from two differences between these groups of animals. First, Arthropods are poikilothermous, birds homoiothermous. The warmer temperatures of parts of Spitsbergen as compared with Bear Island will tend to maintain more southern type of Arthropod fauna in Spitsbergen than on Bear Island, although Spitsbergen is farther north. Birds, being homoiothermous, are relatively less dependent on temperature. Secondly, Arthropods are distributed geographically largely by chance, whereas most birds have a well-developed habit of returning to where they bred or were hatched the year before, and have great powers of flight which normally insure that this takes place.

There is probably not much difference between the relative chances of an air-born Arthropod reaching Bear Island or Spitsbergen. Many birds, on the other hand, could reach either with ease, but have a controlled dispersal and tend to colonize the areas nearest to their ancestral home before those further away; hence there is a stronger southern element in the Bear Island than the Spitsbergen avifauna, correlated with the more southerly geographical position of Bear Island, and in spite of the superior climate of much of Spitsbergen.

To sum up, the Arthropod fauna colonizes by passive chance dispersal and survives wherever conditions are sufficiently good. On the other hand, the dispersal of birds is a more active process and they tend to colonize first those areas nearest the original home.

11. Origins of the fauna

That there has been no post-glacial land bridge between Bear Island and the Palaearctic land mass can scarcely be doubted. Therefore the animals now on Bear Island have either survived from pre-glacial times or colonized since by crossing a wide stretch of sea.

It has frequently been assumed that no life could have existed in Svalbard during a glaciation. If the whole land was covered completely with snow and ice, this was presumably the case, but it seems possible that there was a narrow coastal belt or projecting nunataks or both, free of snow at least during part of the summer. To test whether any animal life could exist in such

conditions the two writers, with B. B. Roberts, investigated the fauna of a nunatak above 3000 ft. at the head of the Emmanuel Glacier, in Liverpool Land, East Greenland, in 1933 (**22**). Under what must be the most severe conditions of ice-free land in the Arctic, a fauna of three species of Collembola, and the larvae of a Chironomid fly (also a single pullus of an Erigonine spider, perhaps not a permanent member of the fauna) were found. Hence these forms at least, and probably also various kinds of mites (see Thor, **30**) might be capable of surviving a glaciation if ice-free land existed. Bear Island is low, and nunataks could scarcely have existed, but the possibility must be borne in mind that certain forms survived on a coastal belt and colonized Bear Island from there.

Thor (**30**) considers that the mites and Collembola of Svalbard represent a pre-glacial element, and adduces three main reasons. First, such forms are extremely resistant to low temperature and could probably have survived, given ice-free land. This we agree in considering possible. Secondly, the members of these groups found in Svalbard are members of the most primitive and least specialized families (with the exception of *Sperchon lineatus*, confined within Svalbard to Bear Island, which Thor considers quite possibly has colonized in post-glacial times). From this Thor argues that these forms, but not the more specialized families, were on Bear Island in pre-glacial times, and that the absence of the specialized forms to-day is due to the absence of post-glacial colonization. This is a doubtful argument, for perhaps both primitive and specialized types may have had opportunity for post-glacial colonization, but only the primitive have found the conditions sufficiently good for survival. Thor also states that it is often the Scandinavian mountain forms, not the coastal ones, which occur on Bear Island, whereas he would have expected the coastal ones to have had better chances of post-glacial dispersal. This also may depend on the relative suitability of the conditions.

Thirdly, Thor states that the postulated means of post-glacial colonization, through drift ice, drift wood, ships, birds and the air, are extremely doubtful for such wingless forms, and certainly cannot account for their wide distribution in Spitsbergen in many fjords and bays which are separated from each other by ice and sea. Such erratic dispersal, so he considers, would result in erratic distributions. With this we agree so far as the first four means of dispersal are concerned, but aerial dispersal cannot now be ruled out so easily, for collections made from heights up to 14,000 ft. by aeroplanes (Coad, **14**), show clearly that mites, Collembola and spiders are not uncommon high in the air. Hence these forms would have had little difficulty in reaching Svalbard post-glacially, though whether in sufficient numbers to account for their present wide distributions is perhaps more doubtful.

The rest of the Bear Island Arthropods and Vertebrates most certainly could not have survived a glaciation, and we believe that all could have colonized in post-glacial times aerially, except for the arctic fox and polar bear

which regularly cross on the ice in winter. Further, as compared with the Palaearctic land mass and with Greenland, those mammals that cannot cross on the ice (lemming, ermine, arctic hare, musk ox) are absent from Svalbard, as are also Lycosid spiders, which is evidence for the absence of a post-glacial land bridge. Elton (**18**, **19**) strongly advocates this view, and also provides data on a remarkable dispersal of insects to Spitsbergen, though Thor (**30**) thinks it conceivable that these were of local origin, which is profoundly unlikely.

If most of the Bear Island fauna has colonized in post-glacial times, there is no reason to suppose such colonization to have finished. In only two groups, the birds and the fresh-water Crustacea, are there adequate comparisons with the past. Among the birds (**4**) there is clear evidence that herring and great black-backed gulls have established themselves only recently, and other more southern species appear to be attempting to establish themselves. Among the Crustacea, Bertram (**2**) has shown good evidence for thinking *Daphnia pulex* to have colonized only of late years, for though previously unrecorded, in 1932 it was widely distributed, being specially common in one lake visited by all previous collectors.

To sum up, all of the Bear Island fauna would have had little difficulty in colonizing in post-glacial times in the absence of a land bridge, and at least among the birds and Crustacea colonization is still continuing. Most forms could not have survived a glaciation, but it is possible that certain Collembola, mites and Chironomid flies represent a pre-glacial element, though they may equally have colonized since.

12. Notes on population control

Observations on the limits to population density in natural populations are still extremely scanty. Within the space of one summer the writers obviously could not contribute anything very definite to this problem, but some remarks (which must be regarded as extremely tentative) on the rather peculiar conditions of Bear Island may not be out of place.

In general the Arctic as compared with Temperate regions possesses few species but many of these are extremely abundant. Bear Island exhibits both tendencies to an extremely marked degree. The paucity of species is obvious from Appendix 1. The major factor involved is probably the severity of the climate, acting both directly and indirectly through the consequent sparseness of the plant life. But it has certainly been assisted by the isolated position of the island; animals which would find Bear Island suitable have not yet colonized. Indeed colonization is still continuing. As a result, Bear Island cannot be considered ecologically "full". Many niches, particularly of larger predators, are empty. For example the bird cliffs would support Accipitrine birds of prey, and the Chironomidae would support many more insectivorous birds.

Though quite a number of species were local or rare, others were extremely

abundant, as illustrated by the large numbers collected. As instances of exceptional abundance, the following may be cited. On one occasion on the mud by a manured lake there was a *continuous* black carpet some 10 yd. long and 1 or 2 yd. broad consisting of a swarm, in many places two to four individuals deep, of *Achorutes viaticus* (each of which is only 2 mm. long). Again on certain days round several of the lakes there was a grey sludge which could be picked up in bucketfulls, this mass consisting entirely of the cast skins of Chironomidae which had drifted ashore. Ichneumonidae are usually met singly or in small numbers, but on the days when the two Bear Island species appeared, they occurred in hundreds. Finally the colonies of sea birds, particularly of common and Brünnich's guillemots in the south, are said to be the largest in the northern hemisphere; their numbers have to be seen to be believed, and certainly even the most crowded British colonies leave one quite unprepared for the spectacle (Pl. 4, phot. 4).

The guillemots are of interest as regards the limit to their density. Almost certainly on so isolated an island their marine food supply is normally far in excess of their needs. Apart from glaucous gulls, which take some of their eggs and young, they normally have no predators. The birds nest on flat ledges, chiefly on the cliff faces, but also over the flat tops of stacks and islets and also on flat areas above the cliffs on the main island where these are separated from the top by further cliffs. But any expansion on to the flat top of the main island would render the birds at once accessible to arctic foxes. Hence the arctic foxes, though normally inoperative as predators, yet may set an effective upper limit to density, i.e. that at which every inaccessible nesting site is fully occupied.

Similar considerations probably apply on Bear Island to the eider ducks, the great majority of which nested on the lake islets, where the nests are extremely numerous. Apart from a few glaucous gulls and arctic skuas which took eggs if the owner was absent, the eider normally had no predators, but though a few pairs bred successfully on the main land, arctic foxes prevent this on a large scale. An arctic fox was seen trying to cross to one of these islets, but gave up on reaching the furthest boulder projecting above the water. (It may be noted that although 1932 was a very late year, no eiders began to nest on the lake islets until the surrounding ice (and the consequent connexion with the main land) had disappeared, Lack (**9**)).

Hence predators limited the number of breeding eiders very materially, as inaccessible lake islets were few. Further, overcrowding on the islets probably reduces the number of offspring reared. Of this a definite example was found; in two nests very close together the one female took under her the clutch of her neighbour who then deserted. (As is well known a number of birds fetch eggs placed outside into their own nest.) The clutches were laid at different times, and the female went off with the first brood to hatch, thus leaving the other clutch of five eggs to die.

Apart from the above birds, where the effect of predators is correlated with overcrowding of breeding grounds, few Arthropods or Vertebrates on Bear Island seemed seriously affected by predators. The ptarmigan, eaten by the arctic fox, are exceptions, and the Mycetophilid and the sawfly parasitized by the Ichneumons may be others. Other cases probably occur, but for the three most prominent groups of land Arthropods, predators seem of little importance. For example, the only important predator of the Collembola was the spider *Coryphaeus holmgreni*, while snow bunting and purple sandpiper probably took a few, but Collembola were abundant in many places where these predators were rare or absent. Similar considerations applied to the Acarina. The Chironomidae were preyed on as larvae by the arctic char, which certainly took a great many to judge from stomach contents, but this fish was absent from many of the smaller ponds where Chironomidae were abundant. Chironomidae were also preyed on as larvae and adults by the arctic tern, but these birds, breeding mainly on lake islets, were extremely local. Adults formed a large part of the diet of the snow bunting, but this bird was scarce and local, in particular being absent from almost the whole of the western part of the northern plateau where nesting crevices were absent. Purple sandpiper, grey phalarope and other birds preyed on them, but all were scarce and local. *C. holmgreni* took them when they were under stones on the colder days, but the Chironomidae were extremely numerous in many places where the spider was absent. Hence although Chironomidae were the basis of the diet of a number of forms, over the greater part of their range the total of predators could in our opinion have had only a negligible effect on their huge numbers. The same applies even more markedly to the Collembola and Acarina, and perhaps helps to explain the enormous numbers of these three groups on Bear Island.

Evidence for animals limited in density by food on Bear Island is small, but is very hard to obtain. The larvae of *Simulium ursinum*, restricted to those streams which drained lakes rich in plankton, may be a case in point, and the arctic fox may be another. But the rate of increase of at least a number of Arctic species cannot be regarded as at all constant, the variation from year to year being due to climatic effects. Two examples were prominent on Bear Island. In 1932 a large number of adult birds (75% or more in some species) failed to breed, and it has been shown (**13**) that this extensive non-breeding occurs frequently in the high Arctic, correlated fundamentally, it is believed, with some climatic factor. Secondly, the number of days on which the air temperature was sufficiently high for the activity of certain winged insects, notably *Stenomacrus pedestris*, was extremely small, and even one sunny day more or less might greatly affect the number of matings in a given year, and the size of the next generation.

Food supply obviously can set an upper limit to the density of population of any animal on Bear Island, and perhaps the populations of many of the

animals are so limited. But the Arctic differs from temperate regions both in the severity of its climate and in the much smaller number of species, particularly of predators and parasites, in the animal communities. It seems possible that the severe and markedly fluctuating climate, affecting both mortality and fecundity, may so greatly modify the usual predator-prey relationships (25) that in places such as Bear Island these may lose much of their normal importance. But until our knowledge is more abundant and precise these are mere hypotheses.

13. Summary

1. The island, its climate and flora are briefly described, and then follows an account of the Vertebrate and Arthropod faunas of the various habitats.

2. Summer temperatures are normally low, but even on the typical foggy days the temperature of the lakes and among plants was several degrees higher than that of the air. Certain winged insects were active in the air only on the extremely few warm days.

3. The humidity is extremely high in summer, contributing to an abundance of mosses and lichens, and of Collembola and Acarina.

4. A characteristic flora and fauna are found on the bird cliffs, some of its members being typical of such habitats farther south and others being typically more widely distributed, but confined to this habitat on Bear Island owing to the severity of the conditions over the general terrain.

5. The land animals were classified in four main groups, the plant communities not being used for this purpose as they often do not correspond with the factors affecting the animals.

6. The Arthropod fauna of Bear Island is more northern in character than that of the inner fjord regions of Spitsbergen, but contains a few southern elements not found in the latter. The avifauna is definitely more southern in character than that of Spitsbergen. The reasons for this contrast are discussed.

7. There has been no land bridge with Bear Island after the glaciation. All of the fauna could have colonized post-glacially, aerially or on the ice, and colonization is still continuing. Most forms could not have survived a glaciation, but certain species may represent a pre-glacial element, though equally they may have colonized since.

8. Though species are few, the individual total is in some cases extremely large, spectacular examples of which are given.

9. The arctic fox, normally inoperative as a predator, may set an effective upper limit, correlated with a limited number of inaccessible nesting sites, to the numbers of guillemots and eiders.

10. It is tentatively suggested that a severe and fluctuating climate, affecting both mortality and fecundity, may greatly modify the predator-prey relationships which have been postulated on theoretical grounds, and which are perhaps typical of temperate regions with a less severe climate and a much greater number of species.

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APPENDIX 1

Complete list of vertebrates and arthropods from Bear Island

(*Note.* As an indication of abundance, notes are given after each species. In the case of the birds, the number denotes the number of pairs as estimated by an approximate census. In the insects and spiders, the number indicates the number of individuals collected by us, which gives a *rough measure* of relative frequency. Species marked * were not recorded by us.)

MAMMALS.

Alopex lagopus	Arctic fox	About 12
**Thalarctos maritimus*	Polar bear	None in summer, 1932, two in winter 1931–32

BIRDS. (Only breeding and possibly breeding species are included; for full list see Bertram & Lack (4).)

Sturnus vulgaris L. (doubtful)	Starling	1
Plectrophenax n. nivalis (L.)	Snow bunting	100
Nyroca fuligula (L.) (doubtful)	Tufted duck	1
Clangula hyemalis (L.)	Long-tailed duck	70
Somateria mollissima borealis (Brehm)	Northern eider	1000
Melanitta nigra (L.)	Common scoter	15
Fulmarus g. glacialis (L.)	Fulmar	Very many
Colymbus immer Brünn.	Great northern diver	2
C. stellatus Pont.	Red-throated diver	80
Charadrius hiaticula L. (doubtful)	*Ringed plover	None in 1932
C. apricarius altifrons Brehm (doubtful)	*Golden plover	None in 1932
Calidris m. maritima (Brünn.)	Purple sandpiper	200
Phalaropus fulicarius jourdaini Iredale	Grey phalarope	12
Sterna macrura Naumann	Arctic tern	250
Larus a. argentatus Pont.	Herring gull	7
L. marinus L.	Great black-backed gull	35
L. hyperboreus Gunn.	Glaucous gull	8000
Rissa t. tridactyla (L.)	Kittiwake	Many
Stercorarius parasiticus (L.)	Arctic skua	175
Alca torda L.	Razorbill	6
Uria aalge hyperborea Salomonsen	Common guillemot	Very very many
U. l. lomvia (L.)	Brünnich's guillemot	Very very many
U. grylle mandtii Mandt	Mandt's guillemot	Fair numbers
Alle a. alle (L.)	Little auk	Very many
Fratercula a. arctica L.	Norwegian puffin	Many
Lagopus mutus hyperboreus Sund	Spitsbergen ptarmigan	3

FISH.

Salvelinus alpinus	Arctic char	Fairly common

INSECTA.

Collembola. (All species recorded by us were numerous except for the two species of Sminthuridae which were scarce.)

Onychiurus armatus (Tullb.) including var. *arcticus* (Tullb.)
Achorutes viaticus (Tullb.)
Xenylla humicola Fab.
Tetracanthella wahlgreni (Axels.)
**Agrenia bidenticulata* (Tullb.)
**Folsomia binoculata* (Wahlgren)
F. quadrioculata (Tullb.)
F. sexoculata (Tullb.)
Isotoma viridis Bourl.
**I. violacea* Tullb.
**I. multisetis* Carp. & Phil.
Smithurides malmgrenii (Tullb.)
Smithurinus niger (Lubb.)
**S. aereus* (Lubb.)

Trichoptera

Apatania arctica Bohem. Common

Lepidoptera

Plutella maculipennis Curt. 2

Coleoptera

Micralymma marinum Stroem.	30
Omalium septentrionis Th.	44
Olophrum boreale Payk.	29
Arpedium brachypterum Er.	26
Enicmus minutus L.	2

Hymenoptera

Amauronematus alberich Benson	12
A. villosus Thoms.	11
Pristiphora frigida Bohem.	16

**Microcryptus erraticus* Holmgr.
**Aclastus gracilis minutus* Bridg.

Stenomacrus pedestris Holmgr.	82
Syndipnus beerensis Roman	78

**Biosteres* sp.

Diptera

Boletina apicalis (Walk.)	45
Exechia frigida Holmgr.	50
Sciara tridentata Rubs.	10

INSECTA (*cont.*)

DIPTERA (*cont.*)

Sciara holmgreni Rubs.	2
Sciara sp. indet.	1
S. consimilis Holmgr.	16
S. parva Holmgr.	10
**S. röderi* Lengersdorf	
Simulium ursinum Edwards	Many larvae, 9 pupae
Pentaneura barbitarsis (Zett.)	4
Procladius crassinervis (Zett.)	40
Diamesa septima Edw.	4
**D. hyperborea* Holmgr.	
**D. ursus* Kieff	
Metriocnemus obscuripes Holmgr.	10
M. ursinus Holmgr.	5
Cricotopus basalis Staeg.	20
Spaniotoma limbatellus Holmgr.	20
S. subpilosus Kieff	17
S. consobrinus (Holmgr.)	Numerous
S. decoratus (Holmgr.)	4
S. mixtus (Holmgr.)	2
**S. festivus* Holmgr.	
**S. petraeus* var. *ursinus* Kieff.	
S. eltoni Edw.	8
S. longicosta (Edw.)	2
Spaniotoma sp. inc.	5
**S. flexinervis* Kieff (? *longicosta* Edw.)	
**S. oxonianus* Edw.	
Chironomus hyperboreus Staeg.	18
C. lugubris Zett.	6
C. psilopterus Edw.	25
Tanytarsus gracilentus Holmgr.	100
T. praecox Goet.	17
T. mimulus (Holmgr.)	60
Trichocera lutea Becher	19
T. maculipennis Mg.	29
Cynomyia mortuorum L.	1
Limnophora megastoma (Bohem.)	61
Scatophaga nigripes Holmgr.	31
Microprosopa frigida (Holmgr.)	5
Leria modesta Mg.	48
L. septentrionalis Collin	39
Piophila sp., cf. *vulgaris* Fln.	1

CRUSTACEA

BRANCHIOPODA

Lepidurus arcticus (Pallas)	Widely distributed
Sida crystallina (Müller)	1 lake
Daphnia pulex (De Geer)	Fairly frequent
D. longispina (Müller)	2 lakes
Macrothrix arctica Sars	6 lakes
Acroperus harpae Baird	1 lake
Chydorus sphaericus Müller	Well distributed

COPEPODA

Cyclops strenuus Fischer	Widely distributed
C. gigas Claus	Well distributed
**C. viridis* (Jurine)	
C. crassicaudis Sars	1 lake
C. vicinus Uljanin	5 lakes
**Maroenobiotus brucei* (Richard)	

OSTRACODA

Eucypris glacialis (Sars)	1 lake
Candona candida Müller	1 lake

ARACHNIDA

ARANEIDA[1]

Coryphaeus holmgreni Thor.	450	*Erigone tirolensis* Koch	10

ACARINA.

Note. The following list and comments are taken from Thor (**30**), except that *Biscirus lapidarius* and *Molgus littoralis* were recorded by us and not Thor. (Thor recorded them from Spitsbergen.) Dr Finnegan wrote that our collection contained eleven species, namely those without asterisks in the following list and also *Hermannia* n.sp., *Pergamasus* sp. deutonymph, *Nothrus* n.sp. and *Eupodes* sp.

**Nothrus horridus* (Hermann)	Very common
**Hermannia reticulata* Thorell	Very common
Ameronothrus lineatus (Thorell)	Rather scarce (Thor) extremely abundant (Bertram & Lack)
**Oribata ursina* Thor	One example
**Dameosome ornatum* (Oudemans)	3 examples
Ceratoppia hoeli Thor (*Notaspis bipilis* var. *sphaerica* (L. Koch))	Not uncommon
**Oribatula exilis* (Nic.)	Fairly common
Murcia notata (Thorell)	Extremely common
**Calyptozetes sarekensis* (*Tragardh*)	Common locally
**Tydeus foliorum* (*Schrank*)	Fairly common
**Eupodes variegatus* Koch	Occasional
**E. clavifrons* Canestrini	Fairly common
**Penthalodes ovalis* (Dugès)	Common
**P. maior* (Dugès)	Not common
Rhagidia gelida Thorell	Fairly common
**Alycus arboriger* Berlese	Fairly common
**Cyta latirostris* (Hermann)	Widespread
Biscirus lapidarius (Kramer)	(Recorded by us not Thor)
**Molgus capillatus* (Kramer)	Common
M. littoralis (Linn.)	(Recorded by us not Thor)
Sperchon lineatus Thor	Local
**Zercon triangularis* Koch	3 examples

[1] The numbers given for the spiders are not directly to be compared with those for the insects.

APPENDIX 2

Acknowledgements

The expedition of which this paper is a result would never have been possible without assistance from many quarters. We must particularly record our gratitude to the Royal Geographical Society and to Magdalene and St John's Colleges, Cambridge, for their financial support. We thank Prof. F. Debenham, Dr T. G. Longstaff, Mr J. M. Wordie, and Mr Charles Elton for invaluable advice concerning the organizing of the expedition and our work in the field, Dr Adolf Hoel for much useful information and a map of the Island, and Prof. J. Stanley Gardiner and the Zoological Laboratory, Cambridge, for encouragement and the loan of zoological equipment. Our particular debt to Mr Elton is obvious from the numerous references in the text to his pioneer work on the animal ecology of Svalbard. We must also thank those specialists who undertook the identification of special groups in our collections: Mr R. B. Benson (Hymenoptera Symphyta), Mr K. G. Blair (Coleoptera), Mr W. S. Bristowe (Arachnida), Dr G. H. Carpenter (Collembola), Mr J. E. Collin (Diptera, part), Dr F. W. Edwards (Diptera, part), Dr S. Finnegan (Acarina), Mr F. W. Gurney (Crustacea), Mr E. Meyrick (Lepidoptera), Mr M. E. Mosely (Trichoptera), Dr J. R. Norman (Fish); and Dr A. J. Wilmott (Plants).

THE SHORE FAUNA OF AMERDLOQ FJORD, WEST GREENLAND

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(*With Plates* 5 *and* 6 *and* 2 *Figures in the Text*)

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1. Introduction

There is a great lack of thorough surveys of the seashore fauna of the Arctic regions, and consequently most of the problems under discussion are purely speculative. The standard work on the West Greenland fauna is still that of Otto Fabricius (1780) in the Frederikshaab district, about Lat. 62° N., since when there have merely been a few scattered notes, such as those of Vanhöffen (1895) at Umanak, Lat. 70° N., and of Kramp (1932) on the Hydroids collected by the "Godthaab" Expedition. On the Oxford University Greenland Expedition of 1936 I had the opportunity of attempting an intensive survey of the shore of Amerdloq Fjord in the Holsteinsborg district, Lat. 67° N., at the time of year when life is most abundant and active. Such a survey is preliminary work in a little investigated field, and is of more value than scattered collections from a wide area. It is intended to raise problems rather than to solve them.

Most of the collections have been deposited with the British Museum (Natural History), and I am indebted to the following for the identifications: Dr I. Gordon (Crustacea), Capt. A. K. Totton (Coelenterata), Dr H. A. Baylis (Turbellaria and Nemertea), Dr C. C. A. Munro (Polychaeta), Dr J. R. Norman, (Fish), Dr Milwyn-John (Echinodermata); and Mr G. Tandy (Algae).

I wish also to express my gratitude to the Committee of the Oxford University Exploration Club for making it possible for a biological party to join the expedition; to the officials of the Grönlands Styrelse and especially to Bestyrer Rasmussen of Holsteinsborg, who did so much to help us in Greenland; and to Mr Charles Elton for his advice and suggestions.

2. Methods

Collections were mostly made by hand at low tide. At the mouths of streams and in pools the water net was used, a coarse one for stirring through the sand and mud and a smaller silk plankton net in clear water to collect microscopic species. In addition a number of collections were taken by a large plankton net towed from a rowing boat or between suitable points on the shore on the flood tide.

The specimens were fixed mostly in formol spirit (45 % spirit, 5 % formalin) or in Bouin's fixative. Specimens fixed by both methods were taken of most of the Annelids, Nemertines and Turbellaria. The Nudibranchs and Actiniaria were anaesthetized in menthol. The preservative was dilute formol spirit (36 % spirit, 4 % formalin), except for some of the Molluscs, which were preserved in 4 % formalin. At the suggestion of Dr J. R. Baker glycerine was added to about 20 % concentration to the soft-bodied worms, which kept them soft for sectioning.

On sand and mud shores the spade and sieve method was used for collecting such forms as *Arenicola marina* and *Pygospio elegans*, but no quantitative work was done by this method. Quantitative estimations were made by a series of counts inside a 15 cm. square. Twenty counts were taken on each of four well defined types of shore community.

A series of water samples was taken at the various collecting grounds at different levels of the tide and at different times, and the salinities later determined. Regular temperature readings at the surface were taken throughout the collecting period.

3. General description

Amerdloq Fjord is situated near Lat. 67° N. just south of the colony of Holsteinsborg. It is some 30 miles long. It is not a fjord in the usual sense, being open to the sea at both ends. At the west it opens into Davis Strait, and eastward by a narrow channel into Ikertok Fjord to the south. The island where the outpost colony of Sarfanguak is forms the southern shore, the northern being the mainland. The shore of the latter is almost uniformly rocky. Steep slabs of dark gneiss granite, with a north-east to south-west thrust, or broken scree and talus are typical. Sand patches are few and widely separated, being found only in the small bays mostly at the mouths of streams. They are rarely as much as 200 m. in length. The southern shore, though not so steep, is similar.

The rise and fall of the tides varies from about 2·5 m. (8 ft.) at the neaps to 3·7 m. (12 ft.) at springs. There are two tides each 24 hr., but the times are very variable, doubtless owing to the presence of a two-way tide through the double entrance of the fjord.

Fig. 1

The conditions therefore are comparable in certain respects with those in a sea loch on the west coast of Scotland or Ireland. A deep entrance and the absence of any large river or glacier opening into it ensure full marine conditions, while its high shores and narrow entrance provide shelter from heavy seas. On the other hand, it is normally ice covered from the end of November till April, and the ice foot, which lies along the shore may persist till well on in May. The effect of the ice on the littoral fauna is extremely important.

The collecting ground was a small bay on the north shore about 15 miles from the entrance. Here there are three stream mouths and several short

stretches of sand beach forming a break in the rocky shore. There are thus examples of each type of shore with the exception of salt marsh and lagoon, which seem to be absent from this part of the Greenland coast.

Fig. 2

4. Survey

(*a*) *Rock shore*

The bare rock shore is very poor in species, though it does support a distinct community. In the lower horizons there is often a thick growth of stunted *Ascophyllum nodosum*[1], *Fucus inflatus* and *F. vesiculosus*, on which are found large numbers of *Littorina saxatilis* var. *groenlandica*. The only other abundant species is *Balanus balanoides*, which occurs on bare as well as on weed-covered rock, and extends farther up the shore than any other species. Most of the specimens are small, and at that time of year there is a good deal of young brood. It seems likely therefore that most if not all of the individuals found on exposed rock have settled in position after the melting of the winter ice foot. Recolonization of this habitat then takes place each summer from those individuals in sheltered crevices lower down the shore or below low-water mark. That growth is very rapid during the short summer months is obvious from the enormous quantity of shed limb casings which floated on the edge of the flood tide.

[1] Species authorities are given in the table on p. 61.

Phot. 1. Rock facies: sheltered spot with thick growth of *Ascophyllum nodosum*. Colonized mainly by *Littorina saxatilis* and *Balanus balanoides*.

Phot. 2. Sand beach: upper beach, showing lines of drift weed.

Associated with this *Balanus balanoides—Littorina saxatilis* community are found a few other species in relatively small numbers. *Mytilus edulis* occurs in sheltered crevices and attached to the base of weed masses. *Gammarus locusta* and *Jaera albifrons* are also found, mostly under loose stones and in crevices. In the bottom of cracks and crevices small Oligochaeta spp. (*Enchytraeus* and *Lumbricillus* spp.? unidentified) and occasional specimens of the Turbellarians, *Procerodes lobata* and *Procerodes ulvae* and of the Nemertine, *Lineus ruber* are found.

In particularly favoured spots and near extreme low-water mark the following species sometimes occur: the Nudibranchs, *Onchidoris fusca* and *Acmaea testudinalis*, the Hydroid, *Laomedea flexuosa* and the Actinian, *Bunodactis stella*, and the Polychaeta, *Eteone longa*, *Phyllodoce groenlandica* and *Eulalia viridis*. The last two are represented by only one or two specimens each, and seem to be visitors from deeper water. All these species are associated with the *Mytilus edulis* bed community, but are the only ones which extend to the rock also.

The series of 20 counts inside a 15 cm. square gave the following results:

	Mytilus edulis	*Littorina saxatilis*	*Balanus balanoides*	Other spp.
1	3	21	75 + brood	—
2	2	46 (small)	117	—
3	1	29	81 + brood	*Gammarus* 3, *Jaera* p.
4	0	31	47 + brood	—
5	1	35	91	*Gammarus* 1
6	1	20	87 + brood	—
7	0	26	102	—
8	0	19	65	—
9	5 (crevice)	19	53	*Gammarus* 1, *Jaera* p.
10	0	35	48	*Gammarus* 4, *Jaera* p.
11	1	25	48 + brood	—
12	0	20	69	—
13	0	18	112	—
14	0	24	81	—
15	1	20	107	—
16	0	12	71	—
17	0	26	63	*Jaera* present
18	2	31	78	*Gammarus* 5, *Jaera* p.
19	5	21	55	*Jaera* present
20	1	21	68	—
Mean	1·15	24·95	75·9	

(*b*) *Sand beach* (*pebble and shingle*)

The noticeable feature of the small sand beaches is the absence of a distinctive fauna. Burrowing worms and Molluscs are absent, and only a very few species typical of other habitats are found. On the beaches investigated there is a regular gradation of the size of sand particles from high- to low-water mark. Fine sand occurs only on the upper part (about 0·75 m. from H.W.S. downward) and is devoid of marine life. Here occur banks of washed-up seaweed sheltering the drift-line fauna. Near low-water springs the shore really consists of pebbles, and here a scanty fauna is found. Scattered *Mytilus*

edulis are attached to the larger pebbles, on which small specimens of *Balanus balanoides* may also occur. *Littorina saxatilis* var. *groenlandica* is fairly common in scattered groups. *Gammarus locusta* is found under the larger stones, and buried in the sand the Nemertine, *Amphiporus lactifloreus* and small Oligochaetes (Lumbricillids and Enchytraeids? unidentified). No other species were found, and all these occur on other types of shore also.

A series of 20 counts inside a 15 cm. square near low-water springs on a sand-pebble beach (Home Beach) gave the following results:

	Mytilus edulis	*Littorina saxatilis*	*Gammarus locusta*		*Mytilus edulis*	*Littorina saxatilis*	*Gammarus locusta*
1	6	1	0	11	7	8	0
2	4	4	0	12	6	3	0
3	3	0	0	13	2	1	0
4	4	8	0	14	3	2	1
5	3	2	6	15	4	2	1
6	3	0	0	16	8	0	0
7	9	0	0	17	5	2	1
8	9	1	0	18	5	1	4
9	4	0	0	19	3	0	3
10	5	1	5	20	6	3	0
				Mean	4·95	1·95	1·05

(*c*) *Stream mouth*

Of three stream mouths, all essentially the same, one was investigated thoroughly. There were extensive sand and mud flats over which the fresh water ran in variable shallow wide channels at low tide. In patches there were coarse shingle and scattered large stones, on which grew the Algae, *Enteromorpha micrococca* f. *bulbosa* and *Capsosiphon aureolus*, also occasional plants of the various Phaeophyceae found along the shore: *Fucus vesiculosus*, *F. inflatus*, *Elachista fucicola*, *Dictyosiphon foeniculaceous*, and *Pilayella littoralis*.

The sloping sides of the stream mouth formed a distinct zone. Here there were moraine boulders and large stones with a thick growth of *Fucus* spp. and *Ascophyllum nodosum*. Here were beds of *Mytilus edulis* near low-water springs.

The salinity of the surface water was naturally lower round the stream mouth than elsewhere. It varied from almost zero (0·08) at low tide to 3·60 g./mille at high water. It may be important however that during the winter months these streams cease to flow, and then the salinity at such places will be the same as that of the open fjord. The temperature of the fresh water was not observed to differ greatly from that of the fjord water. The latter was more variable (see daily readings), whereas the former was relatively constant between 6·5 and 8·5° C. The stream water had a *p*H of 6·6.

The fauna of both zones was essentially similar, though the relative numbers of the species was variable. On the stones and in the beds of *Mytilus edulis* along the sloping sides both *Littorina saxatilis* var. *groenlandica* and *Balanus balanoides* were present in fairly large numbers, the latter mostly as young brood. Single scattered specimens of *Balanus* occurred on stones far up the

Surface water and air temperature readings at Amerdloq Fjord, June and July 1936

N.B. Readings taken daily at 21.00 hrs.

Date	Water °C.	Air °C.	Date	Water °C.	Air °C.
25 June	5·2	4·4	11 July	12·9	9·4
26	8·5	18·9	12	12·9	11·9
27	7·7	7·4	13	12·7	10·2
28	7·7	5·5	14	12·1	7·1
29	10·2	9·1	15	11·6	7·1
30	8·8	6·0	16	13·5	10·7
1 July	11·9	13·5	17	14·8	12·7
2	10·7	7·4	18	9·9	7·4
3	11·0	8·8	19	11·0	10·2
4	12·2	17·0	20	13·8	12·4
5	12·2	9·6	21	11·9	6·6
6	8·5	5·5	22	9·4	6·6
7	9·4	7·1	23	9·4	7·7
8	6·9	6·9	24	10·1	12·1
9	9·9	7·7	25	12·4	14·8
10	10·2	8·8			

mouth of the stream, in water that must be always practically fresh. A series of 20 counts of these three species taken in this habitat gave the following results:

	Mytilus edulis	*Littorina saxatilis*	*Balanus balanoides*		*Mytilus edulis*	*Littorina saxatilis*	*Balanus balanoides*
1	14	12	1	11	9	5	Brood
2	12	8	6	12	10	4	Brood
3	15	3	100 brood	13	12	8	1 + brood
4	15	6	8 + brood	14	13	6	18 + brood
5	21	5	12 + brood	15	10	7	Brood
6	11	15	1	16	13	8	25 + brood
7	13	11	Brood	17	7	8	Brood
8	18	3	Brood	18	7	6	Brood
9	13	5	2 + brood	19	11	7	3 + brood
10	14	11	4 + brood	20	8	9	0
				Mean	12·30	7·65	

Other species present in this zone were *Gammarus locusta* and *Pseudalibrotus littoralis*, and the Isopod, *Jaera albifrons*. Under stones and buried in the sand and mud were the Polychaetes, *Capitella capitata* and *Pygospio elegans*. The latter, however, was far more numerous in the sand flat zone, where the former was correspondingly rarer. In addition there occurred small Lumbricillids and Enchytraeids, and occasional specimens of *Lineus ruber*.

On the sand flats the most noticeable feature was the enormous number of *Pygospio elegans* turned up by digging. Other sand burrowing Polychaetes present were *Capitella capitata*, *Laonice cirrata* and *Cistenides hyperborea* —1 specimen. The last was common, however, in the sand and mud of the *Mytilus edulis* beds some 600 m. distant. In the fresh-water streams running over the sand occurred *Gammarus locusta* and *Pseudalibrotus littoralis*, and on scattered stones were occasional specimens of *Mytilus edulis*, *Littorina saxatilis* var. *groenlandica*, and *Balanus balanoides*. *Arenicola marina*, which was common in the *Mytilus* beds, was absent from the stream mouth sands.

(*d*) Mytilus edulis *beds*[1]

At one particularly sheltered spot extensive beds of *Mytilus edulis* were exposed at low tide, extending vertically about 0·75 m. up from L.W.S. The flat area of sand and mud, with scattered stones and boulders and shallow tidal pools, was thickly covered with *Mytilus*. A series of 20 counts inside the 15 cm. square showed an average of 304·2 individuals per count. Here was found the richest fauna of the shore. The species may be divided roughly into those living in the open on *Mytilus* or attached to weed or to rocks, and burrowing forms found in the sand and mud under stones. The division is by no means clear cut, and many of the former especially showed a wide range in their habitats.

The following species were associated with *Mytilus* in the open. *Balanus balanoides* occurred on every rock and stone and even on large *Mytilus*. On small boulders where *Mytilus* occurred only in a band at the level of the surrounding sand, *Balanus* was scattered over the top as well. *Acmaea testudinalis* and *Cingula aculeus* were common both on *Mytilus* and on open rock in sheltered places, as were also the Actinians, *Bunodactis stella* and *Acthelmis intestinalis*. On sheltered rock, but not usually on *Mytilus* were *Onchidoris fusca* and *Laomedea flexuosa*.

Littorina saxatilis var. *groenlandica* occurred everywhere, on *Mytilus*, rocks, weed and in pools, and *Cingula aculeus* on rocks and weed. Single specimens of an Aeolid (unidentified) and of *Buccinum undatum* (var.) and *Hyas coarctatus* were obtained, the first on *Rhodymenia palmata* in a pool, the other two in rock crevices. *Phyllodoce groenlandica* and *Eulalia viridis* occurred in rock crevices.

Associated more closely with *Mytilus*, living in the shelter of the closely packed beds were *Jaera albifrons*, *Skeneopsis planorbis*, the Polychaetes, *Eteone longa*, *Nainereis quadricuspidata* and *Harmothoe imbricata*. The last occurred under stones, and really belongs to the sand-burrowing forms. In the same habitat were found *Lineus ruber*, *Amphiporus lactifloreus*, and *Notoplana kükenthali* in close-packed *Mytilus* on the under sides of stones. *Lacuna vincta* and *Margarites helicina* occurred mostly on *Rhodymenia palmata* in the pools.

In pools among the weed and sheltering under stones occurred *Pholis gunnellus*. This is interesting, for though *P. gunnellus* is found on both sides of the Atlantic, the species usually recorded from Greenland is *P. fasciatus*. Mr J. R. Norman of the British Museum, who identified it, is inclined to regard the latter as a mere variety of the common species *P. gunnellus*.

In contrast to the rest the following species were almost purely burrowing forms, found buried in the sand and mud mostly under stones and boulders. In open patches more or less free from *Mytilus* occurred *Arenicola marina* in considerable numbers. Other *Polychaetes* were the Terebellid *Polycirrus*

[1] In this area the salinity varied between 7·54 and 27·65 g./mille according to the state of the wind, tide and the amount of fresh water brought down by the stream. In the open fjord it was 33·42 g./mille.

Phot. 3. Stream mouth: upper part, showing boulder beach.

Phot. 4. Beds of *Mytilus edulis*. Stone turned on end to show line of attachment of *Mytilus edulis*: *Balanus balanoides* on upper surface.

medusa, *Cistenides hyperborea*, *Harmothoe imbricata* and *Glycera capitata* single specimen. The Nemertea, *Lineus ruber* and *Amphiporus lactifloreus* mentioned above also occurred, and in addition *Amphiporus angulatus*. The Holothurian, *Chiridota laevis*, was fairly common under large stones.

The series of 20 counts taken on the beds of *Mytilus edulis* gave the following results:

	Mytilus edulis	*Littorina saxatilis*	*Cribrina spitzbergensis*	*Acmaea testudinalis*	*Gammarus locusta*	*Nainereis quadricuspidata*	*Lineus ruber*
1	269	8	1	0	0	0	2
2	359	1	0	0	0	1	0
3	314	11	0	1	0	0	0
4	330	29	1	0	2	0	1
5	279	11	0	0	1	1	1
6	361	14	2	1	0	0	0
7	290	7	0	0	0	5	6
8	222	8	8	1	0	0	0
9	318	6	4	0	0	0	2
10	254	13	0	0	0	0	2
11	368	8	4	0	0	2	0
12	347	23	0	0	0	0	1
13	337	11	1	3	0	4	1
14	253	6	0	0	0	0	5
15	314	16	1	0	1	0	0
16	353	10	0	0	2	2	1
17	280	19	1	0	1	0	2
18	357	15	1	0	1	0	0
19	178	17	0	1	0	6	0
20	301	17	0	0	1	1	0
Mean	304·2	13·05	1·2	0·35	0·45	1·1	1·2

(*e*) *List of the total number of species and their relative abundance in different habitats*

a. = abundant, c. = common, f. = frequent, r. = rare, – = absent.

Species	Habitat: Rock	Sand	Stream mouth	*Mytilus* beds
COELENTERATA				
Laomedea flexuosa Alder	f.	–	–	f.
Bunodactis stella (Verr.)	f.	–	–	c.
Acthelmis intestinalis (Fabr.)	f.	–	–	c.
NEMERTEA				
Amphiporus lactifloreus (Johnston) (*A. groenlandicus*?)	–	f.	–	c.–a.
A. angulatus (Fabr.)	–	–	–	f.
Lineus ruber (Müll.)	f.	–	f.	a.
TURBELLARIA				
? *Notoplana kükenthali* (Plehn)	–	–	–	c.
Procerodes lobata (Schmidt)	f.	–	–	– ? probably present
P. ulvae (Schmidt)	f.	–	–	– ? probably present
POLYCHAETA				
Eteone longa (Fabr.)	r.	–	c.	a.
Nainereis quadricuspidata (Fabr.)	–	–	–	c.
Capitella capitata (Fabr.)	–	–	c.	c.
Harmothoe imbricata (Linn.)	–	–	–	f.
Cistenides granulata (Linn.)	–	–	r.	f.
Pygospio elegans Claparède	–	–	a.	f.?
? *Laonice cirrata* (Sars)	–	–	f.	–

Species	Habitat			
	Rock	Sand	Stream mouth	*Mytilus* beds
POLYCHAETA (*cont.*)				
Polycirrus medusa Grube	–	–	–	f.
Ophelia limacina (Rathke)	–	–	–	r.
Glycera capitata Oersted	–	–	–	f.
Arenicola marina (Linn.)	–	–	–	f.
Phyllodoce groenlandica Oersted	r.	–	–	r.
Eulalia viridis (Müller)	r.	–	–	r.
CRUSTACEA				
Gammarus locusta (Linn.)	c.	c.	?	c.
G. duebeni Lilljeborg	–	–	a.	–
Pseudalibrotus littoralis (Kröyer)	–	–	a.	–
Jaera albifrons Leach	c.	–	–	c.
Hyas coarctatus Leach	–	–	–	r.
Balanus balanoides (Linn.)	a.	f.	c.	a.
MOLLUSCA				
Littorina saxatilis var. *groenlandica* (Olivi)	a.	c.	c.	a.
Onchidoris fusca (Müller)	f.	–	–	f.
Acmaea testudinalis (Müller)	c.	–	–	c.
Buccinum undatum var. (Linn.)	–	–	–	r.
Cingula aculeus Gould	–	–	–	c.
Skeneopsis planorbis (Fabr.)	–	–	–	f.
Mytilus edulis (Linn.)	f.–c.	f.–c.	r.	a.
Aeolidae sp. (unidentified) 1 spec.	–	–	–	r.
Lacuna vincta Mont.	–	–	–	f.
Margarites helicina Fabr.	–	–	–	r.
Lamellibranch, unidentified, 1 spec.	–	–	r.	–
ECHINODERMATA				
Chiridota laevis (Fabr.)	–	–	–	f.
VERTEBRATA				
Pholis gunnellus (Linn.)	–	–	–	f.
ALGAE				
Rhodymenia palmata (Linn.)				
Porphyra miniata Ag. emend. Rosenberg				
Ascophyllum nodosum (Linn.), le Jolis				
Fucus inflatus Linn.				
F. vesiculosus Linn.				
Chordaria flagelliformis (Muell.), Ag.				
Dictyosiphon foeniculaceus (Huds.), Grev.				
Elachista fucicola (Velley), Aresch.				
Pilayella littoralis (Linn.), Kjellem				
Monostroma fuscum (Post. & Rupr.), Wittr.				
Entermorpha micrococca f. *bulbosa* Collins				
Capsosiphon aureolus (Ag.) Gobi				

N.B. All species of Algae except the last two occurred on the rock and *Mytilus* bed habitats. The *Enteromorpha* and *Capsosiphon* spp. occurred in the water of low salinity of the stream mouth. From this station however the following species were absent: *Rhodymenia palmata, Porphyra miniata, Ascophyllum nodosum, Chordaria flagelliformis* and *Monostroma fuscum.*

In addition to the above list small Oligochaetes occurred in variable numbers in all habitats. They were more numerous in the sand and mud under the stones in the *Mytilus edulis* beds and at the stream mouth than on the sand or rock shores, and in all cases were more numerous farther up the shore than near low-water springs. Though unidentified they almost certainly belong to the species *Enchytraeus albidus* (Henle), *Lumbricillus lineatus* (O. F. Müller), and *L. minutus.*

The total number of species found in the intertidal zone is 43, allowing for

at least two species of Oligochaeta, and the numbers occurring in the four habitats investigated as follows:

Rock: 18.
Sand-shingle: 7.
Stream mouth: 14 or 15.
Mytilus edulis beds: 37, minimum (probably 40).

5. DISCUSSION

It is obvious that any discussion of zoogeographical regions must ultimately refer to the physico-chemical conditions under which the animals live, but in an ecological survey a study of the climatic conditions affecting the community is the nearest approach possible to such an analysis. In the case of the littoral community the factors which seem to require consideration are: (1) the temperature of the water; (2) the duration of exposure between tides; (3) the salinity of the water; (4) the intensity of sunlight.

Of course there are a great number of aspects of these factors which may under certain conditions be important; for instance the difference between the air and water temperatures, if extreme, may decrease the maximum period of safe exposure, or again the amount of absorption of sunlight differs greatly on white sand and black rock. It is therefore in a sense false policy to treat these factors as separate entities.

In an Arctic community the important aspects of temperature are the length of time for which the coast is ice-bound each year, the length of the period when temperatures are high enough for active life and growth, and the maximum reached during that period. The duration of the ice covering in Amerdloq Fjord is very variable from year to year. In the more sheltered inland waters such as Maligiak Fjord there may be a solid covering as early as October, and though rather later, Amerdloq is usually frozen by December. It remains solid till the end of April, and is not finally gone till June. The ice foot, which is the solid ice along the shore not rising and falling with each tide, persists longest, and naturally is the inhibiting factor for the littoral fauna. In particularly severe springs, such as that of 1918, it has remained till the end of June. As the first night frosts occur again in September, it is reasonable to suppose that fairly severe freezing will affect the littoral at low tide towards the end of that month, even before the solid winter ice sets in. Thus there is approximately a 3–4 month period more or less completely ice free and a 5–6 month period when the ice covering is solid.

It is worth comparing these conditions with those found by Madsen (1936) between Lat. 70° and 74° N. on the east coast of Greenland. Here the ice in the fjords did not break up till July or even the beginning of August, and began to form again by the middle or end of September, thus giving an ice-free period of not more than 2 months. The greater severity of conditions is reflected in the comparative poverty of the littoral fauna in this district.

Extreme differences in temperature between the water and air may be important in relation to the safe period of exposure. Though the water temperatures cannot fall much below 0° and can hardly ever rise above 15° C., the air obviously shows a much greater range. July maximum temperatures in the sun must rise well over 40°; and though no records are available from Holsteinsborg, the monthly temperature readings from Agto in Lat. 67° 57′ N. show an average of −18·7° C. Of course the minima must be a great deal lower.

Weather Records, West Greenland, 1934

N.B. There are no records of precipitation in the Holsteinsborg district for 1934, but that at Kornok may be regarded as approximately the same as would occur in Amerdloq Fjord.

Agto, Lat. 67° 57′ N., Long. 53° 45′ W., Holsteinsborg district.

	Average temp. (° C.)		Average temp. (° C.)
January	−11·8	July	6·4
February	−18·7	August	6·2
March	−17·3	September	3·5
April	—	October	−1·8
May	−1·8	November	−4·5
June	3·7	December	−7·4

Kornok, Lat. 64° 26′ N., Long. 50° 58′ W., Godthaab district.

	Average temp. ° C.	Precipitation (mm.)		Average temp. ° C.	Precipitation (mm.)
January	−8·9	25	July	10·9	22
February	−9·2	58	August	9·0	8
March	−8·1	6	September	3·0	38
April	0·3	54	October	−0·6	55
May	1·2	6	November	−3·0	53
June	8·0	1	December	−5·9	5

Total precipitation for year 331 mm.

The most obvious difference between this Arctic fauna and that of Boreal or Temperate regions is in the vertical distribution of the animals on the shore. Thus on all the different types of shore studied there is a zone, extending roughly from low-water neaps to the line of drift weed, which is almost bare of life. The only species which occur there in any numbers are *Littorina saxatilis*, Oligochaetes and *Balanus balanoides*. As this bare zone is almost certainly due to the action of the winter ice foot, the occurrence of the last species is of some interest. *Littorina* and the Oligochaetes are capable of arriving there by independent movement after the ice has melted, though the latter may possibly survive the winter buried deep in the sand.

As regards *Balanus balanoides* however the question is whether individuals survive the winter frozen in the ice foot, or whether the whole zone is colonized afresh each summer. There appears to be no direct observation on this point, or on the resistance of *Balanus* to freezing, but certain features noticed during the collecting period (July) give reason to believe that the latter is the case. In the first place all the individuals were small, those on the more exposed places

especially so, and there was a great deal of *spat*, freshly settled. That growth during the short summer period is extremely rapid is shown by the enormous quantities of shed limbs, which floated on the edge of each flood tide. On the other hand, occasional specimens occurred in exceptionally sheltered situations, such as deep fissures in the rocks, which were a good deal larger than the average. These may well be survivors from the year before. They were more frequent near low water than higher up the shore, where there is more likelihood of free water below the winter ice. It is therefore suggested that as a whole the zone occupied by the ice foot is recolonized each spring by the brood of those individuals which survive round about low-water springs and those few occupying especially sheltered positions.

This is in direct contrast with the state of affairs obtaining in temperate waters. Runnström (1925) found that at Bergen the cypris larvae settle on the rocks in April, but the ovaries did not mature till the end of the following year, and the next generation of larvae were liberated the third spring. Most of the adults then died. Hatton & Fischer-Piette (1932) observed that at St Malo the greatest numbers of larvae settled on the most exposed places, and near low-water mark. The period of maximum growth was from April to June, and practically nil during the rest of the year. Moore (1934) confirmed these results at Port Erin, Isle of Man, noting also that larvae which settled in July had no period of rapid growth that year. He found a maximum life period of 5 or 6 years.

Comparing the sizes attained by *Balanus* at St Malo (Lat. 49° N.), Port Erin (Lat. 54° N.) and Bergen (Lat. 60° N.), he found the more northerly specimens to be the larger, those at Bergen being approximately twice as large as those at St Malo, both at the ends of their first and second years. Also at Port Erin Moore found the mortality each year to be greater in the mid-tide region than near high water: 35 and 3% respectively.

Now these conditions are certainly reversed in the Arctic. At Amerdloq *Balanus balanoides* was smaller than British specimens, and, as mentioned above, was more numerous near low water than higher up the shore. This agrees with the findings of Hatton & Fischer-Piette at St Malo. It seems likely therefore that the optimum conditions for the development of *Balanus balanoides* in the littoral are satisfied in the more northerly regions of Boreal waters, possibly even in the Subarctic. Thus both St Malo, and to a lesser extent Port Erin, are to the south of this optimum, while Amerdloq Fjord is to the north. The conditions at Bergen may be some where near the optimum, but in the absence of further observations it is impossible to delimit it more accurately.

Huntsman (1919) records the occurrence of *Balanus* between 4 and 22·5 ft. above low water on a 25 ft. vertical tide in the Bay of Fundy, and also from low water to about 4 ft. on a 4·5 ft. tide on Cape Breton Island. He gives no measurements of size, but his observations show the occurrence of the species throughout the tide range under more severe conditions than at Bergen. Cape

Breton Island at least is ice-bound during some of the winter months. His observations were made in July, and unfortunately he made none of the mortality during the winter.

Obviously if the northern distribution of *Balanus balanoides* is limited by the duration and thickness of the ice foot, it is necessary to determine the resistance of the species to freezing. This is an unsolved question, but there is every reason to believe that a protracted ice foot is fatal. Gurjanova *et al.* (1930) found *Balanus* could survive periods of severe frost up to 48 hr., but Aurivilius (1895) showed that in the Baltic the adults could not survive protracted freezing, certainly not over several weeks, though here the nauplii at that period lie free in the mantle cavity and appear to survive the death of the parent. For the present however the most rational hypothesis is that the northern limit of *Balanus balanoides* is determined by the length and duration of the ice foot.

The reasons for the decline in the species in more southern Boreal waters is more obscure. The most promising line of approach is to attempt to correlate the rate of growth with both the water temperatures and with the length of daylight in different latitudes. As most of the growth takes place in the early summer months, when days are lengthening, it is natural that it should be greatest in more northerly waters, where the length of daylight increases more rapidly during these months, and the total number of hours of sunlight is greater. What connexion this may have with the capacity to withstand exposure to desiccation in the air, for at St Malo most of the specimens occurred near low water, is obscure. The southern limit of the species in European waters is Portugal (Stephensen, 1936).

The recolonization of the ice-foot zone by *Littorina saxatilis* and *Balanus balanoides* each year is a special case of what appears to be general of the Arctic littoral. Thorson (1934) records such species as *Harmothoë imbricata*, *Phyllodoce groenlandica* and *Saxicava arctica* from depths between 3 and 14 m. in the Scoresby Sound and Franz Joseph Fjord, which lie between Lat. 70 and 73° N. on the east coast. Again Summerhayes & Elton (1923) found *Capitella capitata*, *Harmothoë imbricata*, *Ophelia limacina*, *Pseudalibrotus littoralis* and *Gammarus* sp. in depths of 1–3 m. in Lat. 78° 40′ N. on the west coast of Spitsbergen. All these species occurred in the littoral at Amerdloq though in the cases mentioned they were a good deal north of their limit in this community. None of them has been recorded from the littoral north of Angmagssalik (Lat. 66° N.) on the east coast of Greenland, and not at all from Spitsbergen.

There do not appear to be any similar observations of species extending their northern range in the sublittoral from the West Greenland coast, but during the collecting period a marked shoreward migration was noticed in the month of July. Thus certain species, which were uncommon at the spring tides at the end of June, were far more numerous at the next ones a month later.

Onchidoris fusca, *Chiridota laevis*, *Pholis gunnellus*, *Amphiporus angulatus*, *Acmaea testudinalis* and *Laomedea flexuosa* were particularly noticeable in this respect, though no counts were made. The increase in the numbers of *Balanus balanoides* has already been mentioned.

Madsen (1936) has distinguished Arctic and Subarctic (or Boreo-Arctic) areas in the northern littoral. The southern limit of the former is defined as the most northerly stations of *Balanus balanoides* and of marine Molluscs in the intertidal zone, and of the latter as the southern limit of two typically Arctic species of Crustacea, *Mysis oculata* and *Pseudalibrotus littoralis*. Thus the Boreo-Arctic area is that in which Molluscs, *Balanus*, *Mysis* and *Pseudalibrotus* may all occur together. The heuristic value of such a division depends on the world-wide association of these species in the same relation. Thus for the distinction to have any significance it is necessary to show that the southern limits of *Mysis oculata* and *Pseudalibrotus* more or less coincide throughout the world, and the same of the northern limits of *Balanus balanoides* and the Molluscs to which Madsen referred—*Mytilus edulis*, *Acmaea testudinalis*, *Littorina saxatilis*.

There is evidence that on the east coast of Greenland there is a sudden and marked climatic change between Lat. 66° and 70° N. The submarine ridge between Iceland and Greenland is here shallowest, and divides the cold water of the Polar sea from the warmer Atlantic water. It is only south of this ridge that the Irmiger current, a branch of the Gulf Stream, makes its influence felt (Iversen, 1936, in Degerbøl, 1937). The climatic changes associated with this are considerable, the difference between Scoresby Sound (Lat. 70° N.) and Angmagssalik (Lat. 66° N.) being described by Vahl & Hatt (1923), as that between a high or dry continental Arctic and a low maritime Arctic or North Atlantic climate. For corresponding climatic differences on the west coast, where there is no such sudden separation of Arctic and Atlantic waters, a distance over twice as far is required, from Upernivik (Lat. 73° N.) to Godthaab (Lat. 64° N.).

Madsen places the northern limit of his Subarctic area on the east coast to the north of Angmagssalik, probably on the Blosseville Coast round about Lat. 68° N. This area has also been regarded by Degerbøl (1937) as a zoogeographical dividing line for the land fauna as well. The extremely unfavourable conditions on this coast, where numerous large glaciers descend into the sea, may well form a limit to the northern distribution of *Balanus balanoides* and of littoral Molluscs. At Upernivik, which enjoys almost the same climate as Scoresby Sound, they still occur in the littoral (Vinterberg *cit.* Madsen), and their northern limit on the west coast has not yet been found. It is unlikely, however, that Molluscs extend as far as Cape York (Lat. 76° N.). *Balanus balanoides* has been recorded in the littoral from Lat. 78° N. on the west coast (Stephensen, 1936), which is a good deal farther north than littoral Molluscs may be expected.

The crucial point therefore in determining the value of Madsen's division is whether it can hold for a coast on which the climatic change is one of gradually increasing severity to the north, without any such barriers as that of the Blosseville Coast. It should be possible to settle this by a careful study of the littoral of West Greenland from Upernivik northward.

An alternative, and probably more satisfactory, method of testing the value of such zoogeographical divisions is by an examination of the world wide distribution of all the species concerned. If a large block of species can be associated as always occurring together, and their distribution correlated with a certain range of climatic conditions, then such a term as Subarctic may be of use. Of the species found at Amerdloq Fjord, the distribution of *Hyas coarctatus* may be regarded as typical. It has been recorded from the west coast of Greenland as far as 70° 30′ N., but not from the east coast; in North America from the New England coast to the north of Labrador, and from Hudson Bay; from the Mackenzie River mouth, Alaska, Bering Straits and as far south as Korea; in Siberia from Bennett Island, Lat. 77° N., Long. 150° E.; from west Iceland, south and west Spitsbergen, the Faroës, Shetlands, and the Scandinavian coast as far east as the White Sea. It is not known from Lats. 60–135° W., or from 49–150° E., but these are little known areas (Rathbun, 1925).

Such a circumpolar distribution is general for the species occurring in Amerdloq Fjord, many showing a good deal wider range. The British and New England coasts in particular seem to be the southern limit of a large number. For instance all the Molluscs found at Amerdloq also occur off New England (Johnson, 1915), and the following at least in Britain; *Acmaea testudinalis*, *Buccinum undatum*, *Cingula aculeus*, *Lacuna vincta*, *Margarita helicina*, *Littorina saxatilis* and *Mytilus edulis* (Posselt, 1898). The same circumpolar distribution is true for the Polychaetes, *Harmothoë imbricata*, *Eulalia viridis*, *Phyllodoce groenlandica*, *Eteone longa*, *Glycera capitata*, *Arenicola marina*, *Capitella capitata* and *Ophelia limacina* (Ditlevsen, 1914). As shown by Madsen, *Mysis oculata* and *Pseudalibrotus littoralis* have a rather more northern distribution, but *Jaera albifrons* is rather more Boreal (Zirwas, 1910, *cit.* Stephensen, 1913). *Bunodactis stella* is a rather more Arctic species, having been recorded from Lat. 72° N., on the east coast of Greenland, from east Spitsbergen and from Siberia, nor does it occur south of the Faroës in the European or Cape Cod in the American zone.

Laomedea flexuosa has only once been recorded from Greenland, on the south-west coast (Kramp, 1932), and has a more southerly range than most of the other species, extending from the Mediterranean to the Lofoten Islands in Europe; also from south Iceland and New England. The distribution of *Chiridota laevis* is restricted and little known. It is only known from south-west Greenland, north-east America, Spitsbergen, the Kara Sea and Bering Strait, but not from east Greenland, Iceland or Europe (Mortensen, 1913). *Pholis gunnellus* occurs on both British and American coasts.

In view of the extremely wide range of most of the species mentioned it does not appear profitable to use the term Subarctic as descriptive of the fauna as a whole. In other words it is undesirable to use the geographical limits of one or two species for establishing zoogeographical areas, unless they can be correlated with sudden climatic changes, such as the thermocline. As most of the species found at Amerdloq occur also on the British coast and in Spitsbergen, the latter having more rigorous Arctic conditions than the Holsteinsborg district of Greenland, Madsen's Subarctic zone is without significance.

6. SUMMARY

1. A description is given of the littoral fauna of Amerdloq Fjord, Lat. 67° N., West Greenland, during the month of July.

2. The district possesses a rich and varied fauna, composed mainly of species with a circumpolar distribution, and extending in many cases as far south as the British Isles in Europe and the New England coast in North America.

3. Four types of shore are treated separately, namely rock, sand, mouth of a stream, and beds of *Mytilus edulis* on mud, and a series of counts was made of the numbers of individuals of different species occurring within a 15 cm. square from each.

4. It is noticed that the upper levels of the intertidal zone is practically bare of life, and this is attributed to the action of the winter ice foot, which in this district persists for some 6 months in the year. The limiting influence of the ice foot is discussed with special reference to the distribution of *Balanus balanoides*.

5. The usefulness of delimiting a Subarctic area in the littoral, as recommended by Madsen (1936) is discussed. It is concluded that in view of the wide distribution of the majority of the species concerned, such a zoogeographical division is without value, unless it can be restated in physiological (climatic) terms.

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A CENSUS OF THE ECTOPARASITES OF SOME CEYLON RATS

By GORDON B. THOMPSON

Owing to their intimate connexion with plague a vast number of analyses of the fleas found on rats in various parts of the world have been published. As far as I am aware, however, no one has ever published a complete census of the ectoparasites occurring on a rat population. In this short paper I am presenting a complete analysis of the ectoparasites found on fifteen specimens of the common Ceylon rat (*Rattus r. kandiyanus* (Kelaart)). This rat is found everywhere in the vicinity of human habitations throughout Ceylon and it has been the subject of many investigations in connexion with the parasitology of plague (see papers by Hirst, 1926, 1927, 1933).

The whole of the material on which this paper is based was collected by Capt. W. W. A. Phillips, to whom I should like to express my thanks. Most, if not all, of the rats were trapped near his bungalow, on the outskirts of the jungle. The rats were in every case examined as soon as possible after being trapped in order to obtain the maximum number of parasites. It is possible that some of the very small mites (e.g. *Myobia* spp.) were overlooked, but otherwise it seems that the collecting was complete. The determination of the rats was done by the collector, who is a well-known authority on the mammals of Ceylon.

The ectoparasitic Arthropoda found on rats are as follows: Siphunculata (sucking-lice), Siphonaptera (fleas), Acarina (mites and ticks). Representatives of all these groups were collected from the Ceylon rats. Lice were only taken on two of the rats and this scarcity of lice is in accordance with my experience. It is interesting to note that two species are represented. *Polyplax spinulosa* (Burmeister) is the louse normally found on domestic rats wherever they occur. *Hoplopleura oenomydis* Ferris, of which only a single specimen was taken, has a very interesting distribution. It was originally described from various species of Murids occurring in British East Africa and the Philippine Islands. It has since been recorded off *Rattus* spp. from the Marquesan Islands, Federated Malay States, Queensland and Sumatra (Ferris, 1932).

With regard to the fleas, as many as twelve different species have been collected from Ceylon rats. The fact that only four of these occurred on the rats dealt with in this paper is in all probability something to do with the high altitude at which the rats were collected. Flea distribution seems to be largely controlled by environment rather than by their hosts' distribution. This is especially the case with the species *Leptopsylla segnis* Schönhr. which in Europe is extremely common on the house mouse and on rats, but in India and Ceylon

Ectoparasites of the Common Ceylon Rat (Rattus r. kandiyanus (*Kelaart*)) *from C. P. Gammaduwa, Mousakande*

Height and date	No. and sex of rats examined	Ectoparasites: Siphonaptera: Siphunculata	Siphonaptera: *Xenopsylla cheopis* Roths.	Siphonaptera: *Leptopsylla segnis* Schönh.	Siphonaptera: *Stivalius phoberus* Jord. & Roths.	Acarina (mites): *Laelaps nuttalli* Hirst	Acarina (mites): *Laelaps echidninus* Berlese	Acarina (mites): Undetermined genera and species of mites	Ixodoidea: *Ixodes petauristae* Warburton	Total no. of parasites
Alt. 3350 ft., 6. xii. 1934	1	—	—	—	1♀	3	4	—	—	8
12. xii. 1934	1	—	—	—	1♀ 1♂	—	—	—	—	2
16. i. 1935	1	—	—	—	2♀♀ 1♂	—	10	—	—	13
22. i. 1935	1♂	—	—	—	2♀♀	—	—	—	—	2
23. i. 1935	1♂	—	—	2♀♀	1♀	—	—	—	—	3
25. i. 1935	1♂	—	—	—	1♀ 1♂	2	6	—	—	10
28. i. 1935	1♀	1♀*	1♀ 1♂	1♀	6♀♀ 3♂♂	—	—	—	—	13
29. i. 1935	1♀	—	2♂♂	—	1♀	—	—	—	—	3
Alt. 3300 ft., 13. iv. 1935	1	—	—	—	2♂♂†	—	4	—	—	6
Alt. 3400 ft., 28. vi. 1935	1♂	—	—	—	—	—	—	—	1 larva‡	1
28. vi. 1935	1	—	—	—	1♀	—	5	2	3 larvae‡	11
Alt. 3300 ft., 4. vii. 1935	1	—	—	—	1♀	3	4	—	1 nymph‡	9
5. vii. 1935	1	—	—	—	1♀	—	—	—	—	1
13. viii. 1935	1	3♀♀§	—	—	—	—	1	—	—	4
13. viii. 1935	1	—	—	—	1♂	—	—	1	—	2

* *Hoplopleura oenomydis* Ferris.

† Also one female of *Ctenocephalides felis felis* (Bouché).

‡ The nymph of *Ixodes petauristae* Warburton is at present undescribed. The larvae are doubtfully assigned to this species. Dr M. Sharif is publishing an account of the immature stages and I have to thank him for the identifications.

§ *Polyplax spinulosa* (Burmeister).

only occurs in numbers at high altitudes. Hirst (1933, p. 62) points out that *L. segnis* actually predominates on rats at Nuwara Eliga, which is situated in the Central province of Ceylon at an elevation of 7000 ft. From the results tabulated here it seems that *Stivalius phoberus* Jord. and Roths., which is a comparatively large flea and confined to Ceylon, is the commonest species on these rats. It is actually one of the indigenous rat fleas at the highest altitudes and has not been found below 2000 ft. The females are twice as common as the males. Another species of flea, *Ceratophyllus tamilanus* Jord. and Roths., peculiar to Ceylon and found commonly by Hirst (1933) on rats at high altitudes, was not taken by Capt. Phillips.

Ctenocephalides felis felis (Bouché), the common cat flea, of which only a single specimen was taken, is not very common in Ceylon and is almost totally replaced by the subspecies *orientis* Jordan which occurs commonly throughout

the Indo-Malayan regions. *Xenopsylla cheopis* (Roths.) is undoubtedly the most important flea from the point of view of plague and although it only occurred on two rats it is approximately in accordance with the percentage infestation found by Hirst (1926, 1933).

The immature stages of the tick *Ixodes petauristae* Warburton (1933) occurred on three rats and are of great interest, since up to the present only the female of this tick is known. Warburton's specimen was taken from *Petaurista philippensis lanka* (Wroughton) (Ceylon grey flying-squirrel), collected at Mousakande, Gammaduwa, C. P., Ceylon, 3350 ft., v. 1930.[1] The rat must therefore be regarded as a host of the immature stages of this tick and may thus aid in the propagation of the species.

The mites (Laelaptidae, etc.) frequently occur in very great numbers on rats. No great numbers were found on these rats. *Laelaps echidninus* Berlese is a world wide parasite of rats, whereas *L. nuttalli* Hirst seems only to be widely distributed in the tropics.

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[1] These are the correct data for the type specimen—not stated by Warburton (1933).

A SURVEY OF THE DISTRIBUTION OF THE WOOD ANT (*FORMICA RUFA*) IN ENGLAND, WALES AND SCOTLAND

By ENID NELMES

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1. Introduction

This enquiry was begun in 1933 in co-operation with the Bureau of Animal Population game survey, its primary aim being the construction of a map showing the distribution of wood ants in the British Isles, correlated if possible with soil and other factors. This required a consideration of glacial deposits, and as there is no complete drift map of England and Wales it was decided to include rough outlines of drift-covered areas on the distribution map, which would thus serve two purposes. The information supplied is neither detailed nor accurate enough for the map to be used for anything but a preliminary reference, but it is hoped that as such it may be of value.

Records for *Formica rufa* L. (including the varieties *alpina* and *rufo-pratensis*) were collected from various sources. A considerable amount of information was found in the publications of local Natural History Societies; some was obtained through Museums, and a great deal through the kindness of observers all over the country in sending specimens and information in answer to a question in the Bureau of Animal Population's Annual Enquiry for 1933 done by Mr A. D. Middleton. Mr Charles Elton put at my disposal notes

obtained through his Woodland Bird Survey (1930) and inserted a Note in this *Journal* (this appeared also in the *Journal of Ecology*, through courtesy of Prof. A. G. Tansley), and has also passed on records which have come to his notice from time to time. Dr O. W. Richards has identified many of the specimens and given helpful advice: Mr D. F. W. Baden-Powell has given valuable assistance with geological problems. To all of these my thanks are due, and I owe an especial debt of gratitude to Mr Elton, who suggested the survey, for continual encouragement and assistance.

A list of the localities from which records have been obtained, with a brief summary of the information available for each, is given in Table 4. The full data are being deposited in the Bureau of Animal Population.

2. Construction of map

The coastal outline was traced from the Ordnance 10 mile to the inch Physical Map of England and Wales (1925) and the localities from which wood ants had been recorded were plotted as accurately as possible on the tracing, after their position and the nature of the underlying rock had been determined from the drift edition of the 1 in. Ordnance Geological Maps. For the Lake District, most of Wales and the South Midlands, and part of the West Riding of Yorkshire only the solid edition was available. The rock contours were transferred to the tracing by placing it over the Physical Map and copying them from the Ordnance Ten Mile Geological Map; they could not be directly traced owing to a slight discrepancy between the projections of the two maps.

Only boulder clay, and glacial sand and gravel treated together, of the glacial deposits, have been included, and their outlines have been obtained from several sources. The $\frac{1}{4}$ in. Drift Maps were used for East Anglia, and the 1 in. edition for the rest of the country except for those parts mentioned above. In order to complete the outlines in those districts an indication of drift-covered areas was obtained from the map illustrating F. W. Harmer's (**8**) paper on the distribution of glacial drift; but as this shows neither definite boundaries nor the nature of the drift, broken lines have been used for material from this source to distinguish it from the more accurately defined information obtained from the Ordnance Maps.

In some instances the rocks were subdivided according to the nature of the soil to which they more generally give rise and hatched accordingly, with the exception of several which vary a great deal locally. The following table shows the classification adopted, the symbols being those employed in the Ordnance Geological Maps. For the sake of brevity they have been used throughout the tables.

The Purbeck and Portland Beds and the Cornbrash have been included with the adjacent formations on the map because each occupies so small an area that on a map of this size it would be indistinguishable from the neighbouring rocks. The Upper Lias and Middle Jurassic deposits consist mostly of lime-

Table 1

Explanation of symbols

Sand		Clay		Non-calcareous rock		Calcareous rock		Unclassified	
Oligocene Beds	$i^{8\ 11}$	London Clay	i^{3}	Coal Measures	d^{5}	Chalk	h^{5}	Purbeck Beds	g^{14}
Bagshot Beds	i^{4-7}	Gault Clay	h^{3}	Millstone Grit	d^{4}	Carboniferous Limestone	d^{1-3}	Portland Beds	g^{13}
Oldhaven etc. beds	$i^{1\ 2}$	Wealden Clay	h^{1}	Culm Measures	d	Magnesian Limestone	e^{2-4}	Cornbrash	g^{9}
Upper Greensand	h^{4}	Kimeridge Clay	g^{12}	Devonian and Old Red Sandstone	c			Great Oolite, etc.	g^{6-8}
Lower Greensand	h^{2}	Oxford Clay	g^{10}	Upper and Lower Silurian	– b			Inferior Oolite	g^{5}
Hastings Beds	h	Middle Lias	g^{2}					Upper Lias	g^{3-4}
Corallian Beds	g^{11}	Lower Lias	g^{1}	Cambrian	– a				
Keuper Sandstone	f^{5}	Rhaetic Beds	fg.	Pre-Cambrian	– x				
Bunter Sandstone	$f^{1\ 3}$	Keuper Marls	f^{6}	Igneous Rocks:					
Permian Marls and Sandstones	e			Andesite = A. Basalt = B Felsite = F Granite = G Syenite = S					

A, definitel ocality not given; B, on several formations; C, possibly on glacial drift; D, sandstone; E, Cirencester Park; F, Ley Park; G, Trench Wood; H, Sheat Hedges Wood; I, Hay Wood; J, Albyn's Covert; K, records on light clay; L, possibly leached; M, Carnforth.

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Oldhaven etc. beds	i^{1-2}	Wealden Clay	h^1	Culm Measures	d	Magnesian Limestone	c^{2-4}	Cornbrash	g^9
Upper Greensand	h^4	Kimeridge Clay	g^{12}	Devonian and Old Red Sandstone	c			Great Oolite etc.	g^{6-8}
Lower Greensand	h^2	Oxford Clay	g^{10}	Upper and Lower Silurian	– b			Inferior Oolite	g^5
Hastings Beds	h	Middle Lias	g^{2-3}					Upper Lias	g^{3-4}
Corallian Beds	g^{11}	Lower Lias	g^1	Cambrian	– a				
Keuper Sandstone	f^5	Rhaetic Beds	fg.	Pre-Cambrian	– X				
Bunter Sandstone	f^{1-3}	Keuper Marls	f^6	Igneous Rocks: Andesite = A. Basalt = B Felsite = F Granite = G Syenite = S					
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stone in the south and sandstone in the north, and because of this variation they have not been classified, but are indicated by the words "Middle Jurassic". All the Carboniferous Limestone has been marked as calcareous rock, but in the north of England it is composed mostly of sandstones and shales with thin bands of limestone, and so is not strictly calcareous. The Old Red Sandstone of Herefordshire and South Wales has been shown as non-calcareous rock, and no distinction has been made between the rich soil of the Plain of Hereford and the infertile soil of the Black Mountains, as a satisfactory boundary cannot be fixed between them.

Alluvial deposits have been marked as clay. Peat has been indicated where possible, sometimes within definite boundary lines, sometimes by means of scattered symbols, but no distinction has been made between that of moorland and that of fenland origin. The loam on the North Downs and the clay-with-flints on the Marlborough Downs and the Chilterns have been included where possible. River deposits have been omitted, except in some cases where they consist of large tracts of alluvium. No distinction has been made between glacial sand and that derived from underlying rocks.

It has only been possible to map England and Wales in such detail, but an outline map of Scotland on the same scale showing the distribution of wood ants has been made. The information received from Ireland is so scanty that a consideration of its wood ant population has been postponed.

Although efforts have been made to obtain a complete set of records, it is almost inevitable that some have been overlooked. Enough have been found however to give an idea of the way in which the species is distributed over the country, and additions to the list would be welcome. Localities from which reliable records have been received are indicated by solid spots, those needing confirmation by rings, and those where the ants are extinct by dots surrounded by rings.

3. Distribution of wood ants

A. *England*

From a general examination of the map the following points are apparent:

1. The records are scattered throughout the country, but are congregated in groups in certain districts and are absent from large tracts in others.

2. Most of the records are on sand or non-calcareous rock. Clay and calcareous rocks appear to be avoided.

3. On comparison with the physical map it is found that the groups of records generally correspond with hills and the slopes of river valleys, and the bare patches with low-lying ground or with moorland or mountainous regions where trees are scarce or from which they are absent altogether.

For discussion, the map of England has been divided into nine regions each containing one or more groups of records, and five with isolated or few records.

Photo F. Pitcairn

Phot. 1. Nest of *Formica rufa* in pine wood near Coldwaltham, Sussex.

1. *South-east region.* This includes Kent, Sussex, and the London Basin, with Essex and south-east Suffolk. Between the North and South Downs there is a series of alternating sandy ridges with numerous records, and clay lowlands with none. On the North Downs, several colonies are scattered along the loam that covers the chalk in the Rochester district. The land extending eastward between the North Downs and the Chilterns is mostly composed of London clay, and there are several isolated colonies scattered where the soil is light or gravelly, or where there is a local patch of sand, but in the west there are two large patches of Bagshot sand and on these records are concentrated in great numbers.

2. *The Hampshire basin.* This is mostly sand, but there is a narrow belt of London clay devoid of records before the northern chalk boundary is reached. On the sand wood ants are exceptionally plentiful, and the records fall into four distinct groups corresponding with the Great Heath of Dorset, the New Forest, and the districts round Wimborne and Southampton—all below 400 ft. with the exception of much of the New Forest and small patches elsewhere. This comparatively low altitude, with the large numbers of records, are features of interest found also in the Bagshot sands of the South-east region.

3. *The south-west peninsula.* This lies west of a line between Minehead and Exeter and consists of non-calcareous rocks producing moorland and hilly country. Wood ants are scarce throughout the whole peninsula but are to be found near Truro and Minehead, and on the thin siliceous soil of the valleys draining Dartmoor they are plentiful. They are said to occur commonly in the well-wooded valleys between Launceston and Falmouth, and their absence from the northern side of the peninsula is probably due to the lack of trees caused by exposure to wind.

4. *The Jurassic hills.* This includes the Cotswold range ("Middle Jurassic") with the ridge of Corallian to the south-east running parallel to it but separated from it by clay. Most of this land is under pasture and wood ants are not common. They occur sporadically along the Corallian where it is sandy or gravelly, but on the Cotswolds they are confined to one large group on the steep thickly wooded slopes of the Stroud district with one or two isolated localities in Northamptonshire. Near Stroud, despite the number of records, the ants are local and the nests few in number. They are said to occur only in woods facing south, and this may well be so since the sun is effectively cut off from valleys with a northerly aspect by the precipitous slopes facing them. The nests are invariably found in beech or larch plantations, sometimes replaced by birch scrub, on slopes on thin clay overlying oolite. Wood ants are said to be common in Cirencester Park (E), but only two nests have actually been reported from there.

In Northamptonshire the oolitic limestone is replaced by sands, and on these wood ants occur near Stamford and Northampton.

5. *The Welsh border hills.* These extend from the Bristol Channel to

Shrewsbury, and most are composed of non-calcareous rock. The Forest of Dean and the South Shropshire uplands are on poor, infertile soil derived from the Coal Measures. A belt of limestone surrounds the Forest of Dean and there are further deposits in the Malvern Hills. Wood ants occur locally in great numbers in the Forest of Dean, and at Lyth Hill near Shrewsbury where the soil is sandy, derived from glacial drift. Throughout the rest of this region they are scarce, and records generally refer to single nests.

6. *The Pennine Plateau.* This is the central plateau between Derby and the Tyne Gap. The south-eastern portion is non-calcareous rock (Millstone Grit and Coal Measures); the north-western portion is limestone for the most part covered by drift deposits. There is a strip of limestone to the east of the plateau, and a further patch in the south-west.

Wood ants are found on the slopes of the river valleys round the southern and eastern edges of the plateau on the non-calcareous rock. On the whole they are not common, being very local in distribution though often abundant were they do occur. In the West Riding in particular they are scarce, and have in recent years died out in many places where they were to be found formerly.

7. *The Lake District and North Lancashire.* This district consists almost exclusively of non-calcareous Silurian rocks with some glaciation, but there is limestone in the south. The small patch to the north marked as calcareous rock on the map is actually sandstone.

Wood ants are extremely local, as might be expected in mountainous, sparsely wooded country. They do occur in a few places, however, and in some are excessively abundant—notably Ashness Wood near Keswick, Eggerslock Wood on the southern patch of limestone, and Parkhead Wood (D). Here again the colonies are situated on hill slopes.

8. *The moorlands of north-east Yorkshire.* These form a barren plateau drained north and south by deep wooded valleys, and largely composed of sandstones of varying origin which to the north are covered by boulder clay. Oxford clay in this neighbourhood is represented by sandstones and sandy shales. Towards the heads of the valleys the underlying soft Middle and Upper Lias shales are exposed.

Wood ants are local, but have been reported from the slopes of nearly all the valleys running up into the plateau. Along the southern edge every dale has its colony, or has had in the past, but the northern valleys are apparently less suitable. The ants are especially numerous in the pine woods near Helmsley at the south-west corner of the plateau, and in the Hackness Valley near Scarborough. In other places there are a few nests, or the ants have now disappeared. As a general rule they are confined to the wooded parts, but in Baysdale and Jugger Howe Dale and on Silpho Moor the nests are among heather on open moorland.

9. *The Tyne Valley and the Cheviots.* Most of this area has been glaciated. Where the underlying non-calcareous rocks come to the surface they produce

poor infertile soils. As mentioned previously, the limestone is largely replaced by sandstone.

The only large group of records is in the Tyne valley itself, where not only is the species of frequent occurrence in pine woods on sand, but the individuals are numerous also. There are three records from the Coquet Valley where it leaves the Cheviots, several from isolated localities, but in all of these the ants appear to be uncommon with the exception of Chapel Wood, Morpeth, where they are abundant, but restricted to an area of half a square mile.

Before passing to the unfrequented areas the main points arising from the foregoing discussion may be summarized. Infertile soils—i.e. sand, or thin soil derived from non-calcareous rocks—provide the most suitable habitat. On non-calcareous rocks, wooded valley slopes are preferred before low-lying ground, but on sandy soil this is not always the case, as in Hampshire and Surrey. Generally speaking, however, wood ants are likely to be found in hilly country, provided that it is not too high to support woodland. There are very few records from limestone.

The areas from which wood ants are conspicuously absent may now be considered.

1. *The Midland Plain.* This occupies an intermediate position, for records do occur within the area, though not in the plain itself. It forms a rough triangle between the southern edge of the Pennines and the Cotswold escarpment, extending south-west to the Bristol Channel, westward to the Welsh border hills, and north-east to join the Great Clay Vale at Lincoln. This limit is more apparent on a physical map, for at Lincoln the Jurassic rocks fall away to 200 ft. and under, but it coincides approximately with the five records opposite the southern edge of the Lincoln Wolds.

The plain is a large expanse of fertile loams and clay, mostly red except for a band of clay following the line of the Cotswold escarpment. In the north and north-west there are tracts of Bunter sandstones, non-calcareous rocks and sandy glacial deposits producing uplands. Much of the whole area is covered by drift deposits.

There are two plainly distinguished types of country –the heavy red pasture lands of the plain itself, and the infertile, fairly well-wooded uplands rising above it, and it is on the second of these that the wood ants are found, with three exceptions. The first is Ley Park (F) near Gloucester, and beyond the fact that the wood is of conifers no information about local conditions is available. Trench Wood (G) is less certainly on clay. According to the Ordnance Map (solid edition) it is on Lower Lias clay, but there is drift in the neighbourhood and this may extend to the wood itself, as the boundary is indefinite. No information about local conditions has been obtained. At Knowle (A) only the district is given. It appears to be sparsely wooded and quite definitely on Keuper marls, though there is some sandstone near by.

The majority of the records from the uplands are from the Bunter sand-

stone, but there are four from the Igneous and Pre-Cambrian rocks of Charnwood Forest and the Leicester coal-field, and the four Lincolnshire records are from glacial sand.

2. *The Somerset Plain and North Somerset.* This is the wide gap between the Jurassic rocks and the south-west peninsula. Most of it is low-lying pasture or arable land with heavy soil liable to flood, but in the south there is a more elevated tract of greensand producing highly calcareous soil.

As might be expected, wood ants are scarce, occurring at only two places. At Brockley (A), in North Somerset, the exact situation is not given, and there are a number of rock formations in the neighbourhood on any of which the nests may be placed. Ivythorn Wood (B) is on Lower Lias clay and Rhaetic beds, and originally consisted of larch and limes, but these have now been felled, leaving oak. Such vegetation suggests a dry soil, but no information about local soil conditions in the wood is available. The colony is small, and apparently the only one in the district.

3. *The Great Clay Vale.* This enormous tract of land stretches from South Wiltshire to Tees mouth in Yorkshire, but its northern boundary is obscured by drift deposits. It includes the Vales of Oxford, the White Horse, Aylesbury, the Bedford Ouse, Lincoln, York, and Pickering, and the Fenlands. Practically the whole expanse consists of Oxford and Kimeridge clay with Keuper marls. North of Bedford it is modified by superficial deposits of boulder clay, glacial sand and gravel, peat and alluvium, and in the same district there is a ridge of Lower Greensand, also partly obscured by drift deposits.

It is a region of damp pastures and arable land, and from the whole expanse there are only two records, neither from clay. One is from the Greensand, and the other from glacial gravel.

4. *The Lancastrian Plain.* This lies between the Lake District and the South Shropshire uplands, and includes the Cheshire Plain. With the exception of outliers from the Pennines on either side of the River Ribble, it is lowland, and the whole district has been heavily glaciated, and is covered mostly by boulder clay, but there are also large deposits of glacial sand and gravel, and smaller ones of peat and alluvium. The soil is heavy and the north and south are under permanent pasture; the middle portion, on lighter loams, is arable land.

There are only two definite records for wood ants, one from Dunham Park and one from Delamere Forest where they probably no longer exist. An observer who has lived in the district for the past thirty years has never seen them there or anywhere in the neighbourhood, though he considers the conditions to be ideal. They have been reported from the Ribble Valley and from the Leete Valley in Flintshire, but neither record has been confirmed, and the Leete Valley, on limestone, has been described as a very unlikely locality. Their occurrence in the Ribble Valley is more probable, for conditions there resemble more closely those in the valleys of the eastern Pennines, where wood

ants do occur. There the climate is drier, however, and Willoughby Gardner suggests that the scarcity of wood ants on the western side of the Plateau may partly be due to heavy rains during the breeding season.

5. *The Chalklands.* This includes Salisbury Plain, the North and South Downs, the Berkshire Downs, the Chiltern Hills, the East Anglian Chalklands, and the Lincoln and Yorkshire Wolds and as the nature of the soil is varied by local modifications such as leaching and the presence of superficial deposits, the region will be considered in four subsections.

(*a*) *Salisbury Plain, the Dorset Heights and the South Downs.* These consist of pure chalk producing bare downland with few woods, and records are consequently rare. There are three, however, from places where there are local deposits of glacial gravel and clay-with-flints, capable of supporting woodland, but in each the ants are local and scarce. In one the soil is reported to be light. A record from Affpuddle in Dorset more probably refers to the adjacent sand. From the South Downs there are three records, all indefinite. One is for the Brighton district, one for Graffham where the nests are more likely to be on the nearby Greensand, and one for Lewes where several formations approximate. Winged ants have been reported from Dover.

(*b*) *The Chalk Downs.* Reference has already been made to the Rochester district, where loam covers the chalk and wood ants are to be found. They have also been reported from Kingsgate (A) in the extreme east, but again the record is indefinite. The district is sparsely wooded, but there are patches of loam and sand which may support trees and on which the ants may be found.

(*c*) *The Marlborough Downs and the Chiltern Hills.* Here leaching has produced strips of clay-with-flints, supporting beech hangers, along the steep slopes. There are no records from the Chilterns, and two from the Marlborough Downs. Both these are on clay and in both the ants are probably now extinct.

(*d*) *East Anglia, and the Lincolnshire and Yorkshire Wolds.* Much of this region is covered by boulder clay. The soil varies, but is chiefly stiff chalky clay producing arable and pasture lands, and there are no records for wood ants. Between Cambridge and Bury St Edmunds there is a large patch of coarse sands on which wood ants are said to occur, but the record is unconfirmed.

The points gathered from the foregoing discussion may be summarized as follows: Wood ants are generally absent from fertile and heavy clay soils, and from chalk except where local modifications produce a light soil. Low-lying country appears to be avoided.

B. *Wales*

Wood ants are by no means common in Wales, but they are more frequent in the south than in the north. The records are distributed round the coast, with a few in the valleys of the central land mass. Their scarceness in North and Central Wales is no doubt largely due to the barren nature of much of the country. In South Wales they are restricted to the wooded valleys of the coal-

field area, none being reported from the Black Mountains or the south-west peninsula. They appear to be nowhere very abundant, their colonies remaining fairly constant or possibly increasing slightly. There is one record from limestone, for a wood on a slope near Castell Coch where there used to be a nest, but the wood has been felled and the ants have gone. They have been reported from Cwrt-yr-ala (A), where again they appear to be now extinct, but here it is uncertain whether they were on clay or limestone as only the district is given.

C. *Scotland*

The position in Scotland has not been considered in any great detail, but a certain amount of information may be obtained from the distribution map, and from comparisons with physical and geological maps.

The following points stand out clearly from the distribution map:

1. Wood ants are absent from the Southern Uplands and from the Central Lowlands with the exception of West Ayrshire.

2. Most of the records are from the eastern side of the country, and are inland.

3. A few records are scattered along the west coast.

Comparison with the physical map shows that the records form a fringe round the mountain mass of the Highlands, and that they are to be found in all the main river valleys. They do not occur in the mountain mass itself, and are more frequent in the Grampians than the North-western Highlands.

The Grampians and the greater part of the North western Highlands are composed of Pre-Cambrian and Igneous rocks yielding poor infertile soil. Only in the valleys can sufficient soil accumulate to support woodland, and in many of these remnants of primaeval forests persist. In the Highlands, then, the problem of the distribution of wood ants is intimately connected with the distribution of forest land, but although there are records from all the main wooded areas, and although the ants are usually present in immense numbers, they are still local.

Their absence from the eastern coastal strip and the Central Lowlands may perhaps be in part due to the industrial and agricultural activities carried on there. The poor soil of the ancient rocks gives place to rich fertile soils derived from the Old Red Sandstone, and neither this nor the mountain limestone provide particularly suitable habitats. In Western Ayrshire there is a strip of sandy soil along the coast, where wood ants are to be found in the pine woods.

On the Southern Uplands, older rocks appear again, but it is a region of moorland and hill pastures with few woods. In the western dales where woods are more frequent the ants might be expected, but none have been recorded from there. The heavy rainfall may be partly responsible for this.

The few wooded areas along the western coast, and its high rainfall probably account for the scarcity of wood ants there.

D. *Islands*

No records have been received from the Shetlands, Orkneys, Hebrides or the Scillies, from Arran or Lundy, or from Anglesey. There is a record dated 1876 for the Isle of Man, but no details are given, and the forester now in charge of the forest in the northern part has never seen this species in the island. Again, wood ants have been reported from Anglesey, but all efforts to

trace them have been fruitless. In the Isle of Wight, which continues the geological features of the mainland, they are locally fairly abundant on light soils. Of the Channel Islands, the only record is from Jersey, where in 1901 they were common near Grouville Station.

4. Factors controlling wood ant distribution

A. *Frequency tables*

To test the conclusion reached from the distribution map that certain rocks are more suitable for wood ants than others, the average number of records per 100 square miles (frequency) was calculated for each rock formation in England and Wales, and comparisons made (Table 2). The areas were deter-

Table 2

Rock formation	Symbol	Area sq. miles	Total no. of records	No. of records on several formations	No. of records on drift	Frequency No. of records per 100 sq. miles
Oligocene	i^{8-11}	139	13	4	1	9·4
Bagshot and Bracklesham Beds	i^{4-7}	722	107	11	3	14·8
London Clay	i^{3}	1246	24	8	5	1·9
Oldhaven, Reading Beds	i^{1-2}	684	11	4	1	1·6
Chalk	h^{5}	6442	14	9	1	0·2
Upper Greensand	h^{4}	389	2	1	0	0·5
Gault	h^{3}	428	0	0	0	0
Lower Greensand	h^{2}	739	21	2	0	2·8
Weald Clay	h^{1}	582	3	2	0	0·5
Hastings Beds	h	667	17	0	0	2·5
Purbeck Beds	g^{14}	3	1	1	0	33·3
Portland Beds	g^{13}	28	0	0	0	0
Kimeridge Clay	g^{12}	634	1	0	0	0·14
Corallian Beds	g^{11}	170	9	2	0	5·3
Oxford Clay	g^{10}	1436	2	2	0	0·1
Great Oolite, etc.	g^{6-8}	869	4	2	0	0·5
Inferior Oolite	g^{5}	972	17	5	0	1·7
Upper Lias	g^{3-4}	192	7	4	2	3·6
Middle Lias	g^{2}	416	0	0	0	0
Lower Lias	g^{1}	1811	7	4	0	0·4
Rhaetic Beds	fg	45	1	1	0	0·2
Keuper Red Marls	f^{6}	3096	5	5	1	0·16
Keuper Red Sandstones	f^{5}	629	1	0	0	0·2
Bunter Sandstones	f^{1-3}	1437	9	1	1	0·6
Magnesian Limestones	e^{2-4}	610	3	0	0	0·5
Permian Marls and Sandstones	e	654	0	0	0	0
Coal Measures	d^{5}	4034	18	4	2	0·5
Millstone Grit	d^{4}	2083	27	4	2	1·3
Carboniferous Limestone	d^{1-2}	3393	14	4	6	0·4
Culm Measures	d	1193	7	3	0	0·6
Devonian and Old Red Sandstone	c	3599	19	3	0	0·5
Silurian	b^{1-7}	5891	16	3	0	0·3
Cambrian	a	256	2	1	0	0·8
Pre-Cambrian	x	202	1	1	0	0·5
Granite	G	655	6	3	0	0·9

mined from the Ten Mile Geological map by means of an Amsler planimeter, but no measurement of drift-covered areas was attempted, and records from such areas are regarded as referring to the underlying rock, a procedure justified to some extent by the fact that the nature of glacial drift is frequently determined by the rock it overlies. The total number of records for each formation is shown in one column, the number actually on drift in another, and the number referring to more than one formation in a third; the two latter are included in the total, which is the figure used in calculating the frequency.

The frequency figures cover a wide range, from 14·8 (Bagshot beds) to 0·1 (Oxford Clay). The result for the Bagshot beds is exceptional, however, and a more appropriate range would be between 2·8 and 0·1. This excludes the figures for the Corallian (5·3), Oligocene (9·4) and the Purbeck beds (33·3), but all of these are disproportionately great compared with the majority which fall between 1 and 0·1. The high figure for the Purbeck beds is given by the occurrence of one record in a very small area, and as it is uncertain whether it really belongs to the Purbeck beds it is better ignored.

In Table 3 the frequency figures are shown in their appropriate soil groups (Table 1). The Upper Liassic and Oolitic rocks have been omitted because separate sets of figures for the sand and limestone regions would be necessary, and it is impossible to determine them with any degree of accuracy. However, as far as can be discovered, colonies on these rocks are on sand or thin clay.

Table 3

Sand		Non-calcareous rock		Clay		Calcareous rock		Unclassified	
i^{4-7}	14·8	d^4	1·3	i^3	1·9	e^{2-5}	0·5	g^{3-4}	3·6
i^{8-11}	9·4	G	0·9	h^1	0·5	d^{1-2}	0·4	g^5	1·7
g^{11}	5·3	a	0·8	g^1	0·4	h^5	0·2	g^{6-8}	0·5
h^2	2·8	d	0·6	fg	0·22			g^9	0
h	2·5	d^5	0·4	f^6	0·16			g^{13}	0
i^{1-2}	1·6	c	0·5	g^{12}	0·1				
f^{1-3}	0·6	x	0·5	g^{10}	0·1				
h^4	0·5	b	0·3	h^3	0				
f^5	0·2			g^2	0				
e	0								

Despite a certain amount of overlapping the frequency figures fall into three distinct groups:

Group 1. Sandy soils with frequencies greater than 1·5.

Group 2. Non-calcareous soils with frequencies between 1·5 and 0·5.

Group 3. Clay and calcareous soils with frequencies below 0·5.

In Group 1 exceptionally low figures are given by the Bunter sandstones (0·6), the Upper Greensand (0·5), the Keuper sandstones (0·2) and the Permian marls and sandstones (0), and reasons for this will be suggested later. The low figure for the Silurian rocks in Group 2 is not altogether surprising when the large area and the barren nature of much of the country is taken into account. In Group 3 a high figure is given by the London clay (1·9) and this is the most

serious aberration; but there are several modifying factors. Of its 24 records, eight may be on other formations, five more are actually on glacial gravel, and for five more only the district is given, leaving six which may definitely be said to be on London clay. These six, together with the five on drift, give a frequence figure of 0·8 which is nearer the average for Group 3. London clay varies greatly in texture, and in one of the six definite records the soil is known to be light, and in two more the clay is replaced by gravel.

It must be emphasized that in these tables the numbers of *records* for each rock has been used, and that this is no indication of the number of nests, for whereas one record may refer to a single nest, another may refer to dozens. However, with the exception of Symond's Yat, very large colonies are all reported from sand or non-calcareous rock, so no serious misrepresentation is made. It must be remembered, too, that wood ants recorded from sand and non-calcareous rock are generally to be found on those rocks, whereas records from chalk or clay are more often found to refer to sand or gravel.

B. *Records from clay and calcareous rocks*

As clay and calcareous rocks appear to be unsuitable for wood ants, all the records connected with them either theoretically or by definite report will now be examined.

1. *Records from clay.* The Gault and Middle Lias clay have no records, and the Kimeridge clay one. There are three possible records for Oxford clay, but they are all from north-east Yorkshire where it is represented by sandstone and shales. The six records from the London clay have already been mentioned and it may be repeated here that only three of them may be on heavy soil. From the Lower Lias there are two records—Ivythorn Wood, Somerset, which is also on Rhaetic beds and where the soil is probably clay, and Trench Wood (G) which may be on drift. The red Keuper marls of the Midlands and elsewhere provide five records, but only one (Ley Park) appears to be unmistakably on heavy soil. Glacial drift occurs in Sheat Hedges Wood (H) and probably in Hay Wood (I) which is shown on Keuper marls on the Ordnance Map but falls within the hypothetical drift boundaries. The other two are indefinite records—Cwrt-yr-ala (South Wales A), and Knowle (Midland A) and the last named may possibly refer to Hay Wood.

In all these places the soil is assumed to be heavy from the nature of the rock producing it, but there are three records of wood ants actually living on heavy soil. In Albyn's Covert (J) twenty years ago there was one large nest, now gone, and in Daglingworth Wood (E) two large "diseased" nests were found in 1931, but were not expected to persist. On the other hand, wood ants are abundant at Symond's Yat on heavy, clayey soil.

On the light clay at Firestone Copse, Tilsmore Wood, Felcourt Heath, Brogue's Wood and Fox's Cross, wood ants are plentiful and apparently increasing in numbers. Their local occurrence on the thin clay overlying Oolite in

Gloucestershire woods has already been mentioned. The soil here is very dry with a marked calcareous reaction except in the more exposed parts, and the ants, which are found in the open parts of the woods, do not seem to spread to any extent.

In Yorkshire the Inferior Oolite is represented by sandstone and on this the ants flourish. There are four records from the soft shales of the Upper Lias in north-east Yorkshire, but of these one may refer to the adjacent sand. In Arnecliffe Woods (Eskdale) where wood ants were reported formerly, the shales are covered by boulder clay, but as there is no trace of the ants now, it may be inferred that neither kind of clay was favourable. The other two records are from Baysdale, and Stonehouse Wood, near Whitby, where there was formerly a nest from which ants were collected for pheasants. It is possible that they were introduced for this purpose in the first place; there was no colonization and the ants have gone. A similar thing may have taken place in Arnecliffe Woods.

Summary. 1. Wet low-lying clay soils are avoided.
2. Light well-drained clays may support flourishing and increasing colonies.
3. Clay derived from Oolite may support a few colonies, but they do not appear to have spread much.

2. *Records from calcareous soils.* The results from chalk have already been discussed, and it may be repeated here that no wood ants have been proved to occur on it. The records for limestone need examination, and the Carboniferous and Permian limestones may be taken together for this.

Seventeen records have to be considered, and of these four may be dismissed at once as they are in the north of England where the limestone is replaced by sandstone. In the woods crowning Symond's Yat, Great Doward Hill and Coldwell Rocks the soil is leached, and this is very probably the case for six more records from hilly districts (L). One locality may be glaciated (M) and two more may be on other rocks (A, South Wales, Somerset).

The number of records for limestone is, therefore, certainly less than is at first apparent. It may be added that the ants are extinct in six of these places, of which four are in the West Riding where they are believed to have been introduced.

Summary. 1. There are no definite records from chalk.
2. Wood ants are uncommon on limestone, but occur on hilly ground where leaching has taken place.

C. *Soil as a limiting factor*

In attempting to explain the presence of wood ants on certain soils and their absence from others, both the physical and chemical properties of the soil must be taken into account.

(*a*) *Physical properties.* As the underground nest is excavated in the soil itself, the quality of this is of great importance, for if it were close and liable to

become waterlogged it would be difficult to work and aerate and after heavy rain the ants would run the risk of being drowned or suffocated. The unsuitability of heavy clays and chalk is at once apparent, for both retain water and become sticky after rain. Furthermore in dry weather clay becomes hard and cracked and chalk bakes into stony lumps, though the protecting heap of debris might to some extent prevent this happening in the underground nest. In addition, clay may be permanently deficient in air owing to its high water content.

The preference of the ants for a well-drained soil is shown by their close association with hill slopes, departed from only where the soil is sandy and therefore dry. Under these circumstances they can live equally well on low ground, as shown by the large numbers of colonies in Hampshire. This is in accord with the previously noted fact that adequately drained clay soils form quite suitable habitats. Further evidence is provided by three attempts to introduce wood ants into coverts on clay soils at Swanmore, Hants, where they are fairly abundant on the neighbouring sand. The ants flourished up to a point in dry weather but died after heavy rain. At Alderwasley (Derbyshire), too, they abound on sand but are absent from the neighbouring clay lands.

This all points to the conclusion that in the case of clay its property of retaining water renders it unsuitable for wood ants. Calcareous soils, however, are generally dry, despite their tendency towards stickiness after rain, and a further explanation must be sought.

(*b*) *Chemical constitution.* Sandy and poor siliceous soils provide the largest number of records, an overwhelming majority being from sand. Both are poor in mineral salts, especially lime, both have a marked acid reaction, and both contain peaty humus, but sand has a lower basic mineral content than siliceous soils. This is important, and suggests a possible preference for an acid soil. Most clays have an acid reaction, and mention has already been made of their suitability when drainage is assured, except in the case of those overlying Oolitic limestone. These, despite their excellent drainage, are less satisfactory, which suggests that here there is some other disturbing factor—most probably the presence of lime, a conclusion strengthened by the extraordinarily low number of records obtained from the calcareous rocks. In connexion with this evident dislike for lime it may be recalled that no ants are found on the highly calcareous Upper Greensand of East Devon, and that in the open parts of the woods on Oolitic clay where the wood ants made their nests, the soil reaction is more nearly neutral. It may also be added here that in 124 cases out of the 166 where some indication of the vegetation has been given, this is of the acid heathy type.

A further restricting factor seems to be present in red soils from which very few records have been obtained despite their large area. The poverty of the Keuper marls has already been mentioned; there is one record from the Keuper sandstones and none from the Permian sandstones, both of which invariably

form part of the infertile patches in the Midland Plain on which wood ants are to be found. Both produce light soils, and the absence of ants from them is a little surprising. The soil derived from the Devonian rocks (11–13 records) is variable, but the ants seem to be on shales and in one report the soil is said to be a yellow-red shaly clay. Rothney comments on the extreme scarcity of Hymenoptera Aculeata round Dawlish where red soil predominates. From the Old Red Sandstone there are four, possibly five, records; and Dr O. W. Richards states that in the Woolhope district wood ants are found in the Silurian rocks but never on Old Red Sandstone. The absence of ants from south-west Wales which consists largely of this rock has already been remarked.

On the whole, the evidence seems to show that red soils may contain some adverse factor. According to Lord Avebury (**3**) the presence of iron sesquioxides which are injurious to animal life is responsible for the absence of fossils from these rocks, and it may be that they are also in some way harmful to wood ants.

In connexion with soil as a factor controlling the distribution of wood ants, MacLagan's (**9**) experiments on *Smynthurus viridis* (Collembola) may be mentioned. They indicate that the rate and extent of growth, the rate of attainment of sexual maturity, and the number of eggs deposited are all affected by the nature of the soil on which the nymphs are reared. Furthermore when the females are allowed a choice of soils for oviposition, that selected by the majority is found to have a *p*H value of approximately 6·2. It is known that earthworms are most numerous in approximately neutral soils (even slight deviations from the optimum being injurious) and that snails with calcareous shells are restricted to alkaline soils, whereas those with hyaline shells exist over a wide range. Soil actually passes through the body in both *S. viridis* and earthworms, and the harmful effect which might be produced by one differing greatly from the internal physiological condition is easily imagined. In snails, however, the soil must act through the vegetation on which they feed, and in this way it is able to exert a considerable limiting influence on those species with calcareous shells. Wood ants are omnivorous, but depend largely for food on honey dew obtained from Aphides feeding on the surrounding trees. This honey dew is practically unchanged plant sap. Mr Elton has suggested that the preference of wood ants for acid soils may be connected with the manufacture of formic acid which is especially abundant in this species, and if this is so the influence of the soil works indirectly through the honey dew, so removing the ants one step further from the source of their acid supply.

D. *Further factors influencing distribution*

1. *Trees.* In only eight cases have nests away from trees been recorded, though they are quite often under scrub, and in three of these trees were near and were worked for food. Near Lustleigh Cleave there is a nest in a hedgerow; wood ants were previously found in a wood near by, and the present nest has probably originated from there. A large colony was found among gorse and

heather above Dean Wood, Buckfastleigh, and here the tracks of the ants extended all over the wood and also on the moors above the colony. In the hedgerows bordering two lanes near Idless, Cornwall, there are nine nests, with a further one in a hedgebank between the two lanes. In Lady's Wood, on the other side of the village, ants are plentiful, and though it is too far away to be worked by the ants in the lanes they probably originated there. In Jugger Howe Dale and on Silpho Moor, Scarborough, there are a number of nests on open moorland, but these probably spread from the adjoining Derwent Valley in the lower wooded parts of which wood ants are abundant. Elgee (5) mentions wood ants in Baysdale and Great Hograh, both of which are treeless. He considers the occurrence of this species in bare valleys to be an indication of the presence of trees there in the past in accordance with his view that all the moorland valleys were originally forest land. In support of this he adds that in north-east Yorkshire wood ants are only found in old woods and plantations, an opinion generally held throughout the country and supported by their liking for constructing their heaps against tree stumps.

As this species is associated so closely with woods, the felling of trees for timber affects their distribution considerably, and in many places they have disappeared as a result of this. They should be regarded as valuable members of the dry oakwood fauna because of their predilection for the larvae of *Tortrix viridana* which does immense harm to the timber.

2. *Light.* Throughout open-canopied woods the nests may be distributed evenly, but where the shade is more dense the nests are constructed in clearings, along paths and round the edges of the woods. This is strikingly illustrated in Burnham Beeches where a small patch of birchwood contains a number of scattered nests, the surrounding beechwoods having none. In the Cotswold beechwoods the nests are all in the open. However, despite this preference for light, nests are frequently almost completely covered by bracken.

3. *Game preservation.* In many parts this practice is a very powerful factor, and Stainforth considers the absence of wood ants from the East Riding to be largely due to its influence. In some places they have been introduced as food for pheasants; such are Brogues Wood, Kent, and Harleston Firs, Northants, where their numbers increased when game preservation was ceased, and diminished when it was continued. In several places where they were present formerly they have been exterminated by keepers digging up the nests for the young birds, e.g. Lady Park Wood, Durham; Stow Wood, Oxfordshire; Stonehouse and Leeshead Woods, Yorkshire. In the opinion of Mr Rosse Butterfield and Mr W. D. Roebuck, wood ants were introduced into the woods in the western part of north-west Yorkshire, where they are now practically extinct. They are said to have been introduced into Flag Quarry and Brathay Hall Woods, Windermere, for the wild pheasants, and also into Shirlett Woods, Shropshire. Large numbers are taken every year from Stoke Green, Bucks, to Windsor Forest.

Generally speaking, pheasants are not found in the woods containing wood ants, though they may be in others near at hand. Game birds are the chief enemy of this species, but green woodpeckers (*Picus viridis*) may also be responsible for a considerable amount of destruction (**5**).

4. *Fires.* Wood ants are particularly liable to extermination or reduction in numbers by fire on account of their preference for dry, heathy country. This has taken place at Lower Star Post, and Penny Hill, Berks, Bentley Wood, Suffolk; Farnham, Frensham Common, and Pyrford, Surrey, and in West Hampshire and East Dorset.

SUMMARY

1. Maps showing the distribution of wood ants (*Formica rufa*) in England, Wales and Scotland were prepared from data collected from various sources.

2. Wood ants are distributed throughout the whole country, but the records are concentrated in certain districts.

3. On comparison with physical and geological maps it is found that hilly country contains more records than flat, and sandy and siliceous soils more than calcareous and clay soils.

4. Tables showing the frequency with which records occur on different rock formations were prepared. The frequencies for sandy soils are considerably greater than any others; those for clay and calcareous soils are the lowest.

5. Records from clay and calcareous soils are actually fewer in number than is at first apparent.

6. It is suggested that in the case of most clays the high water content is the most important limiting factor, but the chemical constitution of calcareous and red soils is also significant.

7. Further factors influencing the distribution of wood ants are: the presence of woodland; tree felling; the intensity of light; game preservation; fires.

8. Glacial deposits (boulder clay, glacial sand and gravel) have been included in the distribution map for England and Wales.

Table 4

Rocks. The symbols are explained in Table 1. In addition the following have been used: all. = alluvium, b.cl. = boulder clay; g.g. = glacial sand or gravel; c.w.f. = clay-with-flints; L. = loam over chalk; met. = metamorphic rocks; mor. = morainic drift.

Soil. C. = clay; L. = loam; S. = sand; G. = gravel; P. = peat; c.l. = clayey loam; s. = shale; f. = flints; p.l. = peaty loam; s.l. = sandy loam.

Vegetation. A. = ash; Al. = alder; B. = birch; Be. = beech; C. = conifers; E. = elder; L. = larch; O. = oak; P. = pine; S. = spruce; S.c. = Spanish chestnut; Sy. = sycamore; b. = bramble; br. = bracken; h. = hazel; he. = heath; ho. = holly; r. = rhododendron; y. = yew.

Number. The actual number of nests is given where possible. In other cases the following symbols are used: v.n. = very numerous; n. = numerous; c. = common; f.c. = fairly common; n.c. = not common; L. = local; Sev. = several; ex. = extinct.

References. Only published records are given references, the rest being from communications, specimens or personal observation.

Table 4 (*contd.*)

* Specimens have been obtained from these localities

County	Locality	Rock	Soil	Vegetation	No.	Reference
Berkshire	Near Aldermaston Park	g.g.	S.	—	f.c.	—
	Breach Copse, Wokingham	i^6	G.	O.	n.	—
	Burghfield and Mortimer	g.g.	S.	—	f.c.	—
	Caesar's Camp, Camberley	i^6	Poor	P.	1	—
	Crowthorne	i^6	—	C.	—	28
	Kingston	g^{11}	—	O. bushes, C.	—	59
	Lower Star Post, Camberley	i^6	Poor	B. scrub, he.	c., ex.	—
	Palmer's Lake Wood, Wokingham	i^6	G.	P., B.	n.	—
	*Penny Hill, Camberley	i^6	Poor	B. scrub, he.	5	—
	Tubney Wood	g^{11}	S.	B., P., O., Sy.	6	—
	Wellington College	i^3	—	—	—	24
	Windsor Forest	i^3, i^4	—	—	—	—
Brecon	Ystradfellte	d^4, b.cl., g.g.	—	—	—	31
Buckinghamshire	*Burnham Beeches	g.g.	S.	B., ho., he., br.	c.	—
	*Stoke Green	g.g.	G.	P., Be., O.	n.	—
Cambridgeshire	White Wood, Gamlingay	h^2	—	—	—	—
Carnarvonshire	Llanberis	b, a	—	—	—	21
Cheshire	Delamere Forest	g.g., f^4	—	—	? ex.	35
	Dunham Park	b.cl.	—	—	—	35
Cornwall	*Bishop's Wood, Idless	C	c.l. light	O., b.	7	10
	*Blackadown, Idless	C	c.l. light	h., b., ho.	4	—
	Shortlanesend, Idless	C	c.l. light	h., b., ho.	5	—
	Trenowth Wood, Grampound Rd.	C	c.l.	O. scrub	L.	—
Cumberland	Ashness Wood, Keswick	b^2	S.	C., O., scrub	v.n.	—
	Bassenthwaite	b^2	—	—	—	—
	Parkhead, Caldbeck	d^2, d^3	S.	O.	v.n.	—
Denbigh	Crotnant	b	—	—	—	25
	Deganwy	b	—	—	—	25
Derbyshire	Ambergate	d^4	S.	L. mixed	v.n.	—
	*Birch Wood, Cromford	d^4	S.	L. mixed	n.	—
	Cromford	d^4	S.	—	—	—
	Little Eaton	d^4	S.	—	—	40
	*Long Way (Wirksworth)	d^4	S.	L. mixed	n.	—
	*Longshore Wood	d^4	P.	B., P., O., br.	v.n.	—
	*Peat Pills Wood, Alderwasley	d^4	S.	L. mixed	v.n.	—
Devonshire	Bickleigh Vale	C	—	—	—	—
	Bovey Tracey	i^{12}	S.	—	n.	—
	*Bridford Wood	d	S.	O.	50	—
	Buckfastleigh	C	S.	—	n.	—
	*Cannon Teign Wood, Ashton	d	Light	O., S., ho.	1	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Devonshire	Clifford Bridge	d	—	O. and Al. scrub	12	—
	Dawlish	—	—	—	—	45
	Dean Wood, Buckfastleigh	C	C. light	O., Be., he.	v.n.	—
	Fordlands, Exeter	d	—	—	—	—
	Gidleigh Park	G	—	O.	1	—
	Haldon Moor	i	Poor	Be., C.	n.	—
	Holne Bridge	d, e^3	Thin	Be., O.C.	n.	—
	King's Wood, Buckfastleigh	c	S.	O. scrub, C.	v.n.	—
	Kingsteignton	i^{12}	—	—	—	—
	*Lustleigh	G, d	Light	Near O, P, h.	1	—
	Marsh Mills	C	—	—	—	—
	Shaughbridge	C, g.g.	—	—	—	—
	Virtuous Lady Mine	C	—	—	—	18
	Webburn Valley	G, d	G	O. dwarf	9	—
Dorset	Affpuddle	i^2, h^5	—	C.	c.	—
	Bere Heath	i^4	—	Mixed	c.	—
	Bloxworth	i^2, i^3	—	Mixed	c.	—
	Bloxworth Heath	i^4	—	Mixed	c.	—
	Broadstone Common	i^4	S. or P.	C.	2	—
	Bushey	i^4	S.	O., P.	c.	—
	*Cannon Hill, Wimborne	i^4	P.G.	P.	Under 20	—
	Clyffe	i^2, g.g.	—	—	c.	—
	Coombe Heath	i^4	—	Mixed	c.	—
	Coombe Keynes	i^3	—	Mixed	c.	—
	Coombe Wood	i^2	—	Mixed	c.	—
	Corfe	h^2, i^4	—	—	c.	—
	Dudsbury	i^4, i^5	—	O.	c.	—
	East Stoke	i^4	—	P.	c.	—
	Galton	i^2	—	P.	c.	—
	Grange Woods	i^4	—	P. or mixed	c.	—
	Godlingstone Heath	i^4	—	P., O.	c.	—
	Highwood Heath	i^4	—	Mixed	c.	—
	Holme Heath	i^4	—	P.	c.	—
	Holnest	g^{12}	—	—	—	—
	Hyde	i^4	—	P.	c.	—
	Hyde Heath	i^7	—	P.	c.	—
	Lulworth Cove	g^{14}, h^1, h^4	—	—	n.	37
	Middlebere Heath	i^4	—	P., O.	c.	—
	*Morden	i^4	—	P.	n.	—
	Moreton	i^4	—	P., r.	c.	—
	Newton Heath	i^4	—	P., O.	c.	—
	Owermoigne Heath	i^4	—	P.	c.	—
	Parley Heath	i^4	—	—	c.	—
	Povington Heath	i^4	—	P.	c.	—
	Puddleton Heath	i^2	—	P.	c.	—
	Redbridge	i^5, g.g.	—	P., S.c.	n.	—
	Rempstone Heath	i^4	—	P., O.	c.	—
	Sand Banks, Poole	i^4	S.	—	c.	—
	Slepe Heath	i^4	—	P., O.	c.	—
	Stoborough Heath	i^4	—	P., O.	c.	—
	Studland Heath	i^4	—	P., O.	c.	—
	Upper Rockhampton	i^2	—	—	c.	—
	Warmwell	i^4	—	P.	c.	—
	West Knighton Heath	i^4	—	P.	c.	—
	Woodsford	i^4	—	P.	c.	—
	Wool Barrow	i^4	—	Mixed	c.	—
	Wool Heath	i^4	—	P.	c.	—
	Wytch Heath	i^4	—	P., O.	c.	—
	Yellowham Heath	i^2	—	—	c.	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Durham	Chopwell Woods	b.cl., g.g.	—	C.	v.n.	—
	Gibside	d^5	—	—	1	—
	Howgill	d^5, b.cl.	Boggy P.	S., Al.	50	—
	Lady Park Wood, Gateshead	d^5	—	—	ex.	—
	Shotley Bridge	d^4	—	—	1	—
	Staindrop	b.cl.	—	—	—	36
	Winlaton	b.cl., d^5	—	—	—	16
Essex	Bassett's Wood, Little Baddow	i^3, g.g.	—	—	—	—
	Billericay	i^3, i^4	—	—	—	—
	Birdbrook	b.cl.	—	—	—	28
	*Chantry Wood, Wickham Bishops	i^3	c.l., G.	O., A., h., br.	30	—
	High Woods, Colchester	i^3	—	—	v.n.	—
	Hockley	i^3, i^4	—	—	2	—
	Lingwood Common	g.g., l.	—	—	—	—
	*Sparkey Wood, Wickham Bishops	i^3	c.l., G.	O., h., A.	—	—
	Woodham Walter Common	g.g., i^3	—	O. scrub, B.	12	—
Glamorgan	Briton Ferry	d^5, b.cl.	—	—	—	25
	*Brynau Valley, Castell Coch	d^4	—	br.	n.	—
	Castell Coch	d^2	—	—	ex.	—
	Cwrt-yr-ala	f^6, d^2	—	—	ex.?	—
	Pontneath-Vaughan	b.cl., d^5	—	—	—	57
Gloucestershire	Chalford	g^5	—	—	—	60
	Cirencester Park	g^7, g^8	—	—	v.n.	—
	Coldwell Rocks	d^2	—	—	v.n.	60
	*Dark Wood, Woodchester	g^5	C. light	Be.	11	—
	Dean Forest	d^5	—	Be., Ho.	—	30
	Great Doward Hill	d^2	—	—	—	56
	Gorsley	c, b^{6-7}	—	—	—	—
	Ley Park, Westbury	f^6	—	c.	—	—
	Mitcheldean Rd. Station	—	—	—	n.	—
	*Newent Woods	c	—	Be., L.	v.n.	—
	Overley Wood, Daglingworth	g^7	C. heavy	Be.	2	—
	Queens Wood, Much Marcle	b.	—	—	—	—
	Sapperton	g^5	Flagstones	Be.	1	—
	*Sheepscombe	g^5	—	L.	c.	—
	Slad Valley	g^5	—	—	—	60
	Stinchcombe Hill	g^5	—	—	Sev.	53
	Symonds Yat	d^2	Heavy C.	—	v.n.	—
	Ullen Wood, Birdlip	g^5	Thin	Be., L.	4 or 5, ex.	—
	Woodchester Park	g^5, g^4, g^6	C. light	Be.	—	60
	Wotton-under-Edge	g^5	—	—	—	—
Hampshire	*Amberwood, New Forest	i^5	—	O.	n.	—
	Anderwood, New Forest	i^7	—	—	n.	—
	Avon Heath	i^5, g.g.	—	—	—	—
	Biddenfield, Swanmore	i^5	Light S.	—	n.	—
	Bolderwood	i^7, i^6, i^8	—	—	n.	—
	Bournemouth	i^4	S.	P.	n.	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Hampshire	Brockenhurst	i^8	—	—	n.	—
	Broomy	i^5, i^6	—	—	n.	—
	Burley	i^6	—	—	n.	—
	College Woods, West End	i^5	—	P.	c.	—
	Denny, New Forest	i^8, i^7	—	—	n.	—
	Dimmock's Moor, Swanmore	i^5	Light	—	n.	—
	Durford Wood, Petersfield	h^2	—	—	—	—
	Eastleigh	i^5	—	—	—	—
	Farnborough	i^5, i^7	S.	—	c.	—
	Firestone Copse, I. of W.	i^{10}, i^9	C.	P., O.	c.	—
	Fleet	i^5, i^6	S.	—	c.	—
	Godshill, New Forest	i^4, g.g.	—	—	n.	—
	Harewood Forest	c.w.f., g.g., h^5	—	—	Few L.	—
	Harting Combe, Petersfield	h^2	—	—	—	—
	Hartley Wintney	i^5	—	S.	v.n.	—
	Hasley, New Forest	i^5	—	—	n.	—
	Hawley	i^5, i^7	—	S.C.	—	—
	*Headley	h^2	S.	P., O.	2	—
	Highland Water, New Forest	i^6, i^7	—	—	n.	—
	Holiday Hill, New Forest	i^7	—	—	—	27
	Holmhill, New Forest	i^6, i^7	—	—	n.	—
	Holmsley	i^8, g.g.	—	—	n.	—
	Hurn	i^5	—	—	—	—
	Island Thorns, New Forest	i^5	—	O.	1	—
	Knightwood, New Forest	i^7	—	—	n.	—
	*Lady Cross, New Forest	g.g.	—	O., P.	n.	—
	Liberties, Swanmore	i^5	Light S.	—	n.	—
	*Little Linford	i^4	—	P., O.	n.	—
	Lyndhurst	i^7	S. pit	—	—	29
	Mark Ash, New Forest	i^7	—	—	v.n.	—
	Marlboro' Deeps, New Forest	i^{8-11}	—	P.	—	—
	Matchams, Ringwood	i^5	—	—	—	—
	*Milkham, New Forest	i^6	—	—	n.	—
	Minstead	i^6	—	—	v.n.	—
	Norton, I. of W.	i^8	—	—	—	—
	Oakley, New Forest	i^6, i^7	—	—	n.	—
	Pamber Forest	i^4	Light S.	P., O., h.	—	—
	Parkhurst Forest, I. of W.	i^{10}	—	—	—	—
	Picket Hill, Ringwood	i^6, i^7	—	B., b., he., br.	12 ex.	—
	Quab, Swanmore	i^5	Light S.	—	n.	—
	Ramnor Enclosure, New Forest	i^8	—	—	—	29
	Rhinefield	i^7	—	O.	—	—
	*Roe Wood, New Forest	i^6	—	O.	n.	—
	St Leonards	i^4	—	—	—	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Hampshire	Sandy Balls Wood, Fordingbridge	i^4	S., C., G.	P.	v.n.	—
	Sloden, New Forest	i^5	-	—	n.	—
	Sopley Heath	i^5, g.g.	—	- -	—	—
	Spring Woods, Basingstoke	h^5, g.g.	Light	—	n.c.	—
	Southampton	i^5, i^4	—	—	—	17
	*Talbot Wood, Bournemouth	i^4	G.	S.	2	—
	Tunworth	h^5, g.g., c.w.f.	—	O.	n.c.	—
	Ventnor	h^2	—	—	—	44
	*West Moors, New Forest	All	—	O.	—	—
	Wilverley, New Forest	i^7, i^8, g.g.	—	—	n.	—
	Wolmer Forest	h^2	—	—	—	—
Herefordshire	Hollybush Hill	a	Light c.l.	A., br., E.	3	—
	Leominster	c	—	—	—	28
	Woolhope	b	—	—	—	—
Kent	Bedgebury Park, Goudhurst	h	S.	O., S.c., P.	Sev.	—
	Blean Wood	i^3	—	—	v.n.	17
	Bredhurst	L	—	—	—	52
	*British Camp, Oldbury	h^2	S., humus	B., O., P., br., he.	L.	—
	*Brogues Wood, Biddenden	h	C.	P., O., he.	n.	—
	Chattenden	i^3	—	—	n.c.	—
	Chiddingstone	h	—	he.	c.	—
	Cooper's Wood, Canterbury	i^1, g.g.	—	—	—	60
	*Darenth Wood	i^5	S.	—	—	20
	Denge Wood, Canterbury	h^5, L. c.w.f.	—	—	f.c.	—
	*Fox's Cross, Whitstable	i^3	C. light	O. and B.	5 or 6	—
	*Goddard's Green, Benenden	h	S.	P.	—	—
	Hempstead Woods	L	—	—	—	—
	Herne Bay	i^3	—	—	—	28
	Huntingfield	L.	—	—	1	52
	Joyden's Wood, Bexley Heath	i^1, i^2	S.	O., b., h.	1	—
	Kingsgate	h^5, i^1, L.	—	—	—	28
	Maidstone	h^2	—	—	—	52
	Rainham Park	h^5	L.	—	n.c.	—
	Raspit Hill, Oldbury	h^2	S. peat	B.	v.n.	—
	Seal Chart, Oldbury	h^2	—	—	—	—
	Sheppey Cliffs	i^4	—	—	—	28
	Throwley	h^5	—	—	—	52
	Walderslade Road, Rochester	L	—	—	n.c.	—
	Wigmore, Rochester	L	—	—	n.c.	—
	Yelsted Woods	L	—	—	n.c.	—
Lancashire	*Brathay Hall Wood	b	—	O.	n.	—
	Carnforth	b.cl., g.g.	—	—	—	—
	Duddon Valley	b	—	—	—	—
	Eggerslock Wood, Grange-over-sands	d^2	—	y., h.	v.n.	54
	*Flag Quarry Woods, Windermere	b	Light	O., L.	—	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Lancashire	Holker Hall	b, d^3	—	—	—	—
	Satterthwaite	b	Wet	Hardwoods	1, ex.	—
	Silverdale	d^2	—	P., L., O.	n.	—
	Warton Woods	d^{2-3} (?)	—	—	—	—
Leicestershire	Buddon Wood	G	Humus	O., B.	12	27
	Out Wood, Charnwood Forest	A	—	—	1 ex.	46
	Sheat Hedges Wood, Charnwood Forest	f^6, b.cl.	—	—	1 ex.	46
Lincolnshire	Doddington Wood	g	G.	O., C.	6	—
	Skellingthorpe	g	G.	—	—	43
	Troy Wood, Horncastle Spa	g.g.	—	—	—	—
Merioneth	Barmouth	b	—	—	—	—
Middlesex	Enfield	i^3, g.g.	—	—	—	19
	Hampstead	i^4	S.	C.	ex.	39
	Highgate	i^4	—	—	ex.	39
	Wanstead	i^3	—	—	—	—
Monmouth	Penhow	c	—	—	—	—
	Trelleck	c	—	S.	v.n.	—
Northants	*Fox Cover, Harlestone	g^5	Poor	Mixed	—	—
	Harlestone Firs	g^5	Poor	P., he., br.	v.n.	—
	Helpstone Heath	g^7, g^5	—	—	—	—
	Thornhaugh	g^3, g^5	—	—	—	—
Northumberland	Broomley	d^4	—	P.	f.c.	—
	Corbridge	d^4, b.cl.	—	—	v.n.	—
	Devil's Water, Dipton	b.cl.	—	—	v.n.	—
	Dilston	b.cl., g.g.	—	—	f.c.	—
	Dipton Mill	d^5, d^7	—	C. mixed	f.c.	—
	Dipton Wood	d^4, b.cl.	S.f.	P.	v.n.	—
	Harbottle	b.cl., g.g.	—	—	—	—
	Holystone	b.cl.	—	—	—	—
	Lemmington Wood	b.cl., d^1	S.L.	B., P., Be., O., r.	—	—
	Morpeth	d^5	—	C. mixed	v.n.	—
	Riding Mill, Hexham	g.g.	S.	F.	F.	38
	Slaley	b.cl.	S.	P.	f.c.	—
	Styford	d^7, g.g.	—	C.	—	—
	Swallowship, Dipton	b.cl.	—	C.	—	—
	Whitley	b.cl.	—	—	n.c.	—
	Yardhope	b.cl., d^{1-2}	—	—	—	—
Nottinghamshire	Sherwood Forest	f^2	—	—	—	—
	Thorney Wood	g.g.	—	P.	—	—
	*Wigsley Wood	g.g.	S.	O., B., P.	Under 12	—
Oxfordshire	Caversham	h^5, g.g.	S.	—	ex.	—
	Stow Wood, Elsfield	g^{11}	—	B., O.	ex.	—
Shropshire	Albyn's Covert, Bridgenorth	c	C. heavy	B., h., br.	1 ex.	—
	Farley Common	b	—	—	—	—
	Shirlett, Broseley	d^5	P., S.	Mixed C.	f.n.	—
	Spring Coppice, Lyth Hill	g.g.	S.	O.	n.	—
Somerset	Brockley	d^2	—	—	L.	—
	Horner Wood, Porlock	C	—	P.	v.n.	12
	*Ivythorn Wood, Street	g^1, fg.	—	O., P.	3	—
	Minehead	C	—	—	—	—
Staffordshire	Bishop Wood, Eccleshall	f^2	—	O., L.	1	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Staffordshire	Burnt Wood	f^2	—	—	—	—
	Cannock Chase	f^2, d^5	—	—	—	—
	Hopwas Wood	f^2	L.	C.	—	—
	Idlerocks Estate, Moddershall	f^2	—	—	—	—
Suffolk	Assington Thicks	b.cl.	Poor	O., B., h., P.	2	—
	Bentley Wood	b.cl.	—	P.	f.n., ex.	—
	Holbrook Park	g.g.	—	—	—	—
Surrey	Ashstead	i^3	—	—	—	14
	Bagshot	i^6	—	—	Sev.	—
	Blackheath	h^2	—	—	—	—
	Byfleet	g.g.	—	—	—	—
	Catford	i^3	—	—	—	—
	Chobham	i^5, i^6	—	—	—	—
	*Esher Common	i^4	S.	P.	f.c.	—
	Farnham	h^2	—	P.	—	28
	Guildford	h^5	—	—	—	—
	Horsell	i^4	—	—	—	28
	*Jumps Estate, Farnham	h^2	S.	P.	1 ex.	—
	Limpsfield	h^2	—	—	—	14
	Long Cross	i^4, i^5	—	—	—	49
	*Milford	h^2	—	P.	—	—
	Oxshott	i^4	—	P.	f.c.	—
	Pyrford	i^4	—	—	—	24
	St George's Hill	i^5	—	—	—	21
	Shere	h^2	—	—	—	17
	*Thursley Common	h^2	S.	P.	4	—
	Weybridge Heath	i^4	—	—	1	21
	Woking	i^4	—	—	—	29
Sussex	Abbot's Wood, Eastbourne	h^1	—	O., C.	c.	32
	Ashling Wood	i^3	—	O.	—	—
	Balcombe Forest	h	—	P.	f.c.	—
	Bolney Woods	h (?)	—	—	—	—
	Brighton District	h^5	—	—	c.	50
	Broadstone Wood, W. Hoathly	h	—	—	—	—
	*Champs, Coldwaltham	h^2	S.	P.	1	—
	Coates, Fittleworth	h^2	S., P.	P., B.	3	—
	Creep Wood, Battle	h	S.	P.	20	—
	Crowborough Warren	h	—	—	—	—
	Eridge Forest	h (?)	—	—	—	—
	*Felcourt Heath	h	P., C.	B., Be., O., br.	2	—
	Graffham	h^5, h^2	—	—	—	13
	Guestling Wood	h	—	—	C.	—
	Heatherden Wood, Cross-in-hand	h	—	—	n.c.	—
	Hindleap Warren, W. Hoathly	h	—	—	—	—
	High Woods, Bexhill	h	—	—	—	25
	Horncastle Wood, W. Hoathly	h	—	—	C.	—
	Lewes	h^1	—	—	—	—
	Midhurst	h^2	—	C.	—	—
	Priestridge Warren, W. Hoathly	h	—	—	—	—
	St Helen's Wood, Hastings	h	—	—	C.	—
	Tilgate Forest	h	—	P.	f.c.	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Sussex	Tilsmore Wood, Cross-in-hand	h	P., C., S.	P.	n.	—
	Vetching Wood	h (?)	—	—	—	—
	Worth Forest	h	—	P.	f.c.	—
	Wych Cross Place, W. Hoathly	h	—	—	ex.	—
Warwickshire	Hay Wood, Knowle	f^6	—	—	—	22
	Knowle	f^6, g^1	—	—	—	42
	Sutton Coldfield	f^2	S.	B., O., he., br.	—	—
Westmoreland	Arnside	d^2	—	—	—	—
	Low Wood	b	—	—	—	25
Wiltshire	Rabley Wood, Marlborough	h^5, c.w.f.	—	—	c.	—
	Selwood Forest	h^4	—	S.	2	—
	West Wood, Marlborough	h^5, c.w.f.	—	—	ex.?	—
	Whetham	g^{11}	—	—	ex.?	—
Worcestershire	Bewdley	d^5	—	—	—	—
	Shrawley	f^5	—	—	—	34
	Trench Woods	g^1	—	—	—	34
	Wyre Forest	d^5	S.	O., B.	v.n.	—
Yorkshire	Arnecliffe Woods, Glaisdale	g^3, b.cl.	—	P.	ex.?	51
	Baysdale	g^3	—	he.	—	—
	Barnscliffe Woods, Langdale End	g^5, g^{10}	C.	O., P.	n.	—
	Blackhills, Wilsden	d^4	P.	P., B., he.	f.c., ex.	—
	Bloody Beck, Langdale End	g^5	C., P.	he., br.	—	—
	Bradfield	d^4	—	P.	Sev.	41
	Brockodale Woods, Wentbridge	e^2	—	—	—	—
	Crimsworth Dene, Hebden Bridge	d^4	—	—	Sev.	—
	Dalby Valley	g^{11}	S.	C.	—	—
	Denby Dale	d^5	—	P.	C.	—
	Duncombe Park, Helmsley	g^5	Light	P.	f.c.	—
	Eagle Hall Grounds, Pateley Bridge	d^4	—	—	ex.?	—
	Farndale	g^5, g^3, g^1	—	—	—	—
	Goitstock, Bingley	d^4	—	Mixed	n., ex.	—
	Grass Low Wood, Grassington	d^2	—	—	ex.	—
	Great Hograh, Commondale	—	—	O., B., he.	n.	—
	Hardcastle Crags, Hebden Bridge	d^4	—	—	C.	—
	Hebden Bridge	d^4	—	—	v.n.	—
	Honley	d^4	—	—	—	—
	Jugger Howe Dale, Langdale End	g^5	C.	he.	—	—
	Kirkstall Woods	d^4	—	—	—	—
	Leeshead Wood, Littlebeck	b.cl.	C., light	B., O.	l, ex.	—
	Levisham Woods	g^{11}	—	—	—	—
	*Newton Dale	g^{11}	—	P.	—	—
	Pickingill, Ripon	—	—	—	—	—
	Ravensgill, Pateley Bridge	d^4	—	—	ex.	—
	Riccal Dale	g^{11}, g^{10}	Light	P.	n.	—
	Silpho Moor	g^{11}	—	he., P.	n.	—

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Yorkshire	Stonehouse Wood, Littlebeck	g^3	Light clay	Be., O., L.	1, ex.	—
	Sprotboro' Woods	e^{2-4}	—	—	—	—
	Wakefield District	d^5	—	—	ex.	—
	Weldon Wood, Fryaton	e^2	—	—	—	—
	West Ayton	g^{11}, g.g.	—	—	—	—
	Wharncliffe Crags	d^5	—	—	—	—
SCOTLAND:						
Aberdeenshire	*Bannockbuie Forest, Balmoral	g.g.	Thin humus	P., S., L.	v.n.	—
	Braemar	b.cl., g.s.	—	—	—	19
	Brig of Gairn	—	—	—	—	31
	Craig Gowan, Balmoral	x	Thin humus	P., S., L.	v.n.	—
	Garmaddie, Balmoral	g.s.	Thin humus	P., S., L.	v.n.	—
Ayrshire	Barrhill	b.cl.	—	P.	—	11
	Fusherton Wood, Dunure	B	P., dark	L.S.	3 or 4	—
	Kilmarnock	—	—	—	—	11
	Mauchlin	e	—	—	—	11
	Mochrum Wood	c	—	—	—	11
	Water of Girvan	d.c.	—	—	—	11
Argyllshire	Armidale Wharf	all., met.	p.l.	B., h.	v.n.	—
	Colintraive	met.	—	P.	f.c.	—
	Loch Awe	met.	—	—	—	—
	Loch Tyne	F	—	O.	—	—
	Loch Sween	met.	—	B.	—	—
	Strontian	—	—	—	—	—
	Tighnabruaich	met.	—	P.	f.c.	—
Elgin	Logie	g.g.	—	—	—	—
Inverness	Aviemore	S, G	—	—	—	30
	Forest of Glenmore	b.cl., met.	—	—	n.	—
	Nethy Bridge	S, G	S. or G., humus	P.	v.n.	—
	Rothiemurchus	G	—	P.	v.n.	—
	Strathglass	met., mor.	—	P., B.	n.	—
Kinross	Blair Adam Estate	B	—	—	—	—
	Cleish Castle Woods	A	—	—	—	—
Nairn	*Collyuish Wood, Dunphail	—	Mossy	P.	v.n.	—
	Dulsie Wood, Dunphail	g.s. and g.g.	Mossy	P.	v.n.	—
	Greystone Wood, Dunphail	b.cl.	Mossy	P.	v.n.	—
	Shaw Wood, Dunphail	b.cl.	Mossy	P.	v.n.	—
Perthshire	Aberfoyle	met, c	—	—	—	33
	Abernethy Forest	S, G	—	—	—	—
	Black Wood, Rannoch	mor.	—	—	—	23
	Brig o' Turk	met.	—	—	—	33
	Cambusmore	c, all.	—	—	—	33
	Carie Glen, Killin	met., mor.	—	—	n.	—
	Chuallaich	met., b.cl.	—	—	—	—
	Coninish Glen	met.	—	P., br.	21	—
	Glen Suie	met.	—	—	—	59
	Loch Ard	met.	—	—	—	33
	Loch Tummel	mor., b.cl.	—	—	—	59
	Pass of Leny	met.	—	—	—	33
	St Filans	met.	—	—	c.	—
	Trossachs	met.	—	—	c.	33

Table 4 (*contd.*)

County	Locality	Rock	Soil	Vegetation	No.	Reference
Renfrewshire	Paisley	d^{1-2}	—	—	—	14
Ross-shire	*Corrie Valighan	—	—	B.	12	—
	Garve	met., mor.	—	—	v.n.	—
	*Guchbae, Garve	b.cl.	—	B.scrub	v.n.	—
	Loch Scalpey	G	—	B.	3	—
Stirling	Rowardennan	met.	—	P.	f.c.	—
Sutherland	Inveran	mor.	—	B.	n.	55
	Invershin	mor.	—	B.	n.	55
	Loch Shin	—	—	—	—	26

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SOME NOTES ON THE PLANKTON OF THE THAMES ESTUARY

By A. LAURENCE WELLS

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1. Introduction

The precise limits of the estuary of the River Thames are not easy to define. The Thames Conservancy's eastern limit (Crowstone to Yantlet) is generally acknowledged as forming the end of the river itself, although, geographically and physically, the head of Sea Reach makes a more satisfactory boundary. The western limit, however, is the subject of some controversy. The jurisdiction of the Port of London Authority extends to the meridian of Havengore Creek and for Custom's purposes the Estuary extends to a line drawn from Reculver Towers on the Kent coast to a point just below Clacton-on-Sea on the Essex side. A glance at the chart of the area in question (Fig. 1) will show that the typical estuarine sandbanks continue some miles farther eastward. For this reason, doubtless, Captain Tizard, R.N. in his Hydrographical Surveys in the *Triton*, 1882–9, gives the eastern boundary as being a line from the North Foreland, Kent, to Harwich, Essex, via the Kentish Knock Lightvessel (Fig. 2). The "Company of Free Fishermen of the River of Thames", and indeed all ruling bodies of that river since Norman times, also gave the aforementioned line as the limit of their jurisdiction and for the purposes of this paper that limit will be assumed.

The Second Ice Age, it is generally agreed, was responsible for the present peculiar formation of the Estuary. The north-east trend apparently results from the course of the river, when, with the Rhine, it flowed (supposedly) through what is now the North Sea. The supposition is that with the rapid

melting of the ice—the ice barrier ended, as far as Essex was concerned, at what is now the River Crouch valley—a channel was formed to the south, and Britain became an island. This has resulted in an intricate network of currents and a corresponding maze of sandbanks. The peculiar vagaries of the currents persist as far up-river as Gravesend and it is a well-known fact, that, off Southend, while the tide is flowing rapidly to the west, a set of currents may be proceeding in the opposite direction.

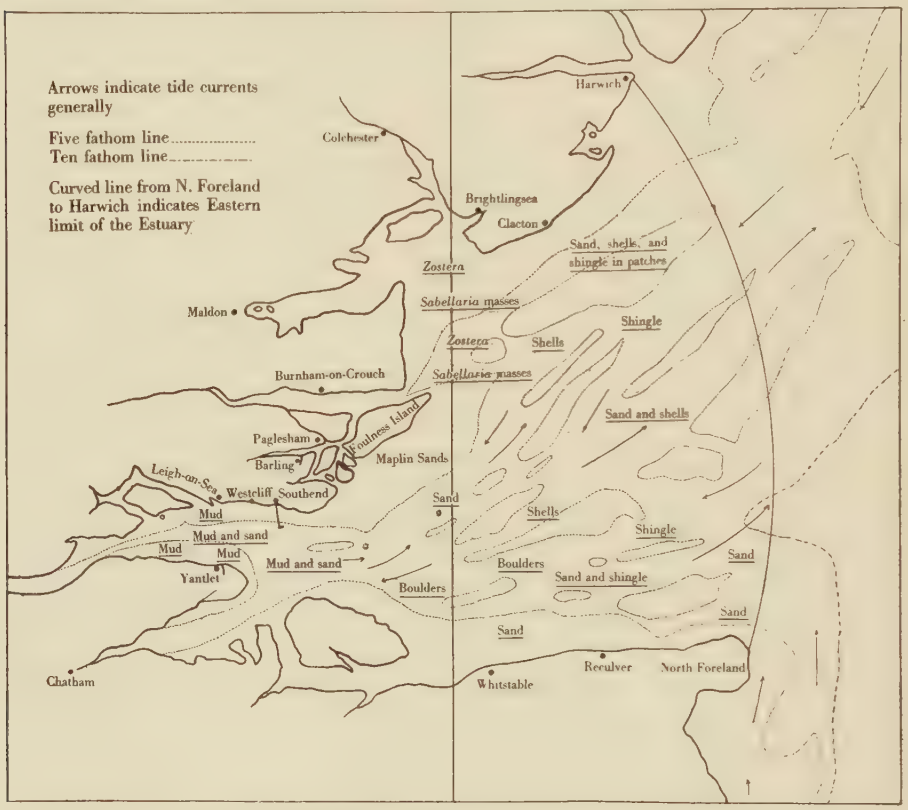

Fig. 1. Thames estuary showing currents and sea bed.

Moreover, there are not infrequently, circular eddies of wind caused by the land mass of the Isle of Thanet and the prevailing north-east winds: these eddies, which have been noted by ballistic experts at the School of Coast Artillery at Shoeburyness, seem to have their origin off Reculver and move in a northerly direction over the Girdler Sands. The unstable currents and the peculiarities of the wind may have some effect on, indeed they may be the reason for, the presence in the plankton of organisms that do not properly belong there.

For these peculiarities alone a survey of the plankton of one particular area may show very different results from one made, say, a hundred yards away. To

complicate matters further the two banks of the river are differently constructed, both physically and geologically.

The Essex bank is low-lying and, in places, characterized by extensive mud flats and large spits of gravel; Foulness archipelago and Canvey Island, the largest of these gravel spits, being reclaimed by the Dutch in the seventeenth century. The Foulness archipelago, consisting of the islands of Potten, Havengore, New England, Wallasea and Foulness itself form a dividing line between

Fig. 2. Thames estuary.

the northern part of the Estuary and the main channels. Foulness Spit, projecting some 15 miles (at low water) to the north-east further emphasizes this division. The southern aspect of Foulness is characterized by the extensive Shoebury, Maplin and Foulness Sands which are contiguous and are noted as cockle beds of great value. The foreshore here slopes gently, the tides receding to the fairway, an average of 2 miles from high-water mark.

The north bank of Foulness is steep-to and in the bight formed by this, the Dengie Flats, and the estuaries of the Colne and the Blackwater, are large stretches of *Zostera*, housing eels and other fishes and a great Crustacean population. The average depth here, at high water, is 5 fathoms. In this

miniature "firth" there is, without doubt, a richer fauna than in any other well-defined part of the estuary. The sheltered aspect is conducive to the breeding of oysters; the *Zostera* makes an excellent spawning ground for fishes with demersal eggs, and the comparatively large tracts of sea-bed covered with the sand-aggregated tubing of *Sabellaria* and *Pectinaria* literally swarm with divers members of the Caridea and other groups of the Crustacea. From the mud of the adjoining creeks the tides bring multitudes of diatoms, mostly Naviculoid.

Conditions on the Kent bank are very different. With the exception of the Medway Estuary and the Isle of Sheppey which divides the mouth of the River Swale, the coast line is more or less unbroken. From Whitstable to the Cant Edge, hard sand is revealed at low water, and the off-shore waters are liberally sprinkled with boulders washed from the London Clay. This same London Clay, from the erosion of Sheppey, is believed to increase the diatom population, and is therefore largely responsible for the food of the Whitstable oysters. The boulders and the rocky aspect of the coast towards the North Foreland attract a more diverse and plentiful number of crabs than elsewhere in the Estuary. Round the Foreland start the scallop beds of the south-east coast. An occasional scallop (the species found hereabouts are *Pecten maximus*, *P. opercularis*, *P. varius* and *P. pusio*) may be dredged west of the Nore, but is considered a rarity. Nevertheless, juvenile scallops and the megalopa stage of crabs, quite unknown to the Essex bank, find their way into the plankton of that side.

The common prawn (*Leander serratus*, Pennant) is most prolific off the North Foreland but its erratic wanderings take it as far up river as Sea Reach. The brown shrimp (*Crangon vulgaris* Linn.) is found everywhere in the Estuary; the pink shrimp (*Pandalus montagui*, Leach), on the other hand, prefers the north-east and more seaward area, increasing in numbers until, off Harwich, it is sufficiently plentiful to warrant a separate fishery. This Pandalid does not breed in the Estuary, an autumnal migration takes them off the Suffolk coast, and there, or possibly somewhere north thereof, they breed. Their larvae have yet to be found in the Estuary proper.

2. Methods

(*a*) *Methods of obtaining samples*

With few exceptions the samples of plankton were taken from the extension at the end of Southend Pier, about $1\frac{1}{4}$ miles from the shore. Here, at Springs, the water is some 6 fathoms deep. 200 m. nearer midstream there is about 10 fathoms at normal high tides. The principal steamer channels of the Outer Estuary may be as deep as 14 fathoms.

Ordinarily the tide recedes to within a quarter of a mile of the Pier head.

The net principally used was a small Apstein (made of silk containing 60 threads to 1 in.) and this, owing to the strength of the tide, had to be weighted fore and aft with 2 lb. weights. Occasional samples were taken with a 180-mesh Apstein but this net seemed to collect so much silt as to spoil the sample.

Samples taken other than from the Pier head are not here given in detail. They were taken in the River Crouch off Burnham-on-Crouch, Barling Creek, the River Roach at Paglesham, the River Blackwater off Mersea, and off Foulness Point. The Kent coast was not touched, in a plankton sense, during this research; on a number of occasions I have used ordinary beam trawls on that side of the Estuary, principally off the Cant Edge and in Sea Reach, when reviewing the benthic fauna. Regarding the samples taken in the estuaries forming the northern part of the Estuary, these were made usually with the 60 Apstein net; at other times, for purely faunistic purposes, masses of *Zostera* were washed for diatoms and copepods.

The Pier-head samples were taken at roughly fortnightly intervals between 20 November 1933 and 27 November 1934, during which period thirty hauls were made. From November 1934 until April 1937 hauls were made at monthly intervals. For several good reasons the samples were not taken at regular intervals, not the least being that the strength of the tide, at different points of its flood, varies considerably, giving a corresponding variation in the size of the catch (see Fig. 3). As near as possible samples were taken every fortnight. As they were all taken at 12 noon and at 2 hr. before high water, it happened, in practice, that some were a week apart and others as much as 3 weeks.

The net was used from the west side of the Pier and in all cases lowered to 1 m. below the surface for 10 min. Although taken from so near the surface (normally there were 4 fathoms of water at the point used) the haul contained a considerable quantity of sand and other detritus from the bottom. The detritus took the form of spicules from various species of Porifera (sponges), including *Leuconia nivea*, *Derutus Bucklandii* and *Stelletta* sp. (I have to thank M. Burton, Esq. of the British Museum (Natural History) for the identification of most of the spicules); Echinoderm spines, comminuted pieces of bivalve shells, coal dust, etc. On the other hand, shoals of whitebait at times played around the mouth of the net, yet none occupied any of the samples obtained. The form of the material varied, presumably, according to the strength of the tides; sometimes the greater part of the sample would consist of sand and at others would have the appearance of one taken many miles from shore. The collections are deposited in the Fisheries Laboratory, Lowestoft.

(*b*) *Methods of counting samples*

Immediately on removal from the net the material is killed with formalin. Later it is poured into a large Petri dish and the larger organisms, such as fish larvae, Amphipods, Decapod zooeae, etc., are removed. The remaining material

is then placed in a beaker and the volume made up to 100 c.c. and well stirred. With a graduated pipette 1 c.c. is drawn off and deposited on a squared slide and the organisms contained thereon examined and counted under the microscope.

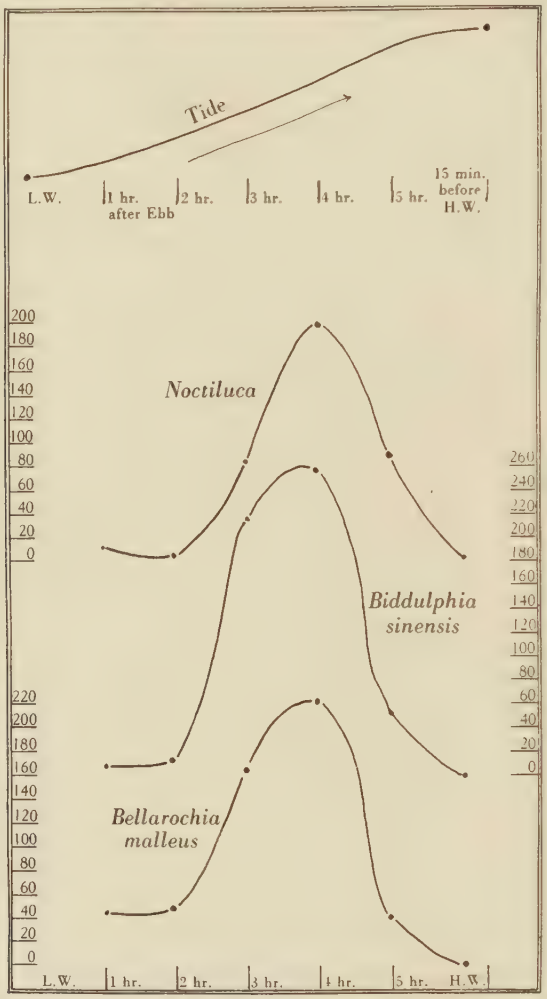

Fig. 3. Variations in the quantities of the three principal organisms of the hauls made at different states of the tide, 17 Sept. 1934, in thousands per ten minutes' haul.

If the sample is a particularly rich one the material drawn off in the pipette is further diluted. The organisms thus counted are multiplied by the extent of the dilution—by 100, 250, 500 or even 1000 as the case might be. By this means the numbers of the predominant organisms can be gauged fairly accurately. The principal drawback to this method of counting is that a small patch of an insignificant organism may form part of the ultimate matter

counted and so give a rather distorted result. This is likely to happen in any form of fractional counting.

The alternative method of placing a small quantity of stirred, but undiluted, material on a slide and counting all organisms up to a hundred—or a thousand, if necessary—and thus arriving at a percentage suffers from the same fault.

Both methods were used in counting the series of samples taken on 17 September 1934. There was no appreciable difference in the actual results.

3. Variation in the plankton at different stages of the tide

In order to ascertain more exactly the variation in the plankton at different stages of the tide, on 17 September 1934, I took six samples at hourly intervals —the first at ½ hr. after dead low water and the last at ½ hr. before high water.

Analyses of the six hauls are here given.

½ hr. after ebb. 1.30 *p.m.*

		Macroplankton	
Bellarochia malleus	59,700		
Noctiluca miliaris	8,200		
Biddulphia sinensis	6,300	*Idothea baltica*	13
Chaetoceros subtilis	6,300	Post-larval pipe-fish (*Syngnathus acus*)	2
Lithodesmium undulatum	3,600		
Biddulphia mobiliensis	750	*Gammarus* sp.	1
Actinoptychus splendens	150		
Gasteropod ova	150		
Acartia clausi	150		
Total number of organisms	85,300		

1½ hr. after ebb. 2.30 *p.m.*

Bellarochia malleus	49,500		
Biddulphia sinensis	13,800	Post-larval polychaete	1
Noctiluca miliaris	6,600	*Oikopleura dioica*	1
Chaetoceros subtilis	5,700	*Sagitta elegans*	1
Biddulphia mobiliensis	600	Decapod larvae	1
Lithodesmium undulatum	600		
Polychaete larvae	300		
Acartia clausi	300		
Total	77,400		

2½ hr. after low water. 3.30 *p.m.*

Biddulphia sinensis	217,800		
Bellarochia malleus	163,200	*Idothea baltica*	16
Noctiluca miliaris	84,000	*Sagitta setosa*	2
Lithodesmium undulatum	73,800	*Pleurobrachia pileus*	1
Biddulphia mobiliensis	52,200	*Porcellana* megalopa	1
Chaetoceros subtilis	31,800		
Coscinodiscus concinnus	900		
Acartia clausi	7,200		
Harpacticid sp.	1,200		
Centropages hamatus	900		
Gasteropod ova	900		
Copepod nauplii	600		
Macropsis slabberi	600		
Polychaete larvae	600		
Polychaete post-larvae	300		
Oikopleura dioica	300		
Brachyura larvae	300		
Total	636,600		

$3\frac{1}{2}$ *hr. after low water.* 4.30 *p.m.*

Biddulphia sinensis	245,400		
Bellarochia malleus	210,000	*Idothea baltica*	53
Noctiluca miliaris	187,200	Pipe-fish, immature (length 12 mm.)	1
Biddulphia mobiliensis	55,800		
Lithodesmium undulatum	54,000	*Paratylus swammerdami*	1
Chaetoceros subtilis	12,900	*Caprella linearis*	1
Coscinodiscus concinnus	6,600	Brachyura larvae	1
Rhizosolenia stolterfothii	1,500		
Nitzschia closterium	300		
Acartia clausi	9,000		
Centropages hamatus	3,000		
Euterpina acutifrons	1,500		
Balanus nauplii	1,500		
Polychaete larvae	900		
Copepod nauplii	900		
Macropsis slabberi	900		
Longipedia scotti	600		
Balanus balanoides, cypris larvae	600		
Oikopleura dioica	600		
Decapod larvae	300		
Gasteropod ova	300		
Harpacticid sp.	300		
Polychaete post-larvae	300		
Total	794,400		

$4\frac{1}{2}$ *hr. after low water.* 5.30 *p.m.*

Noctiluca miliaris	93,300		
Biddulphia sinensis	55,500	*Porcellana* megalopa	5
Bellarochia malleus	41,100	*Caprella linearis*	1
Chaetoceros subtilis	21,600	*Autolytus prolifer* (metasome larva)	1
Biddulphia mobiliensis	15,000		
Lithodesmium undulatum	9,900	Larval pipe-fish (length 22 mm.)	1
Rhizosolenia stolterfothii	3,000		
Coscinodiscus concinnus	1,800		
Acartia clausi	3,900		
Copepod nauplii	1,200		
Polychaete larvae	600		
Centropages hamatus	600		
Macropsis slabberi	600		
Balanus, cypris larvae	300		
Gasteropod ova	300		
Oikopleura dioica	300		
Pecten sp. juv.	300		
Total	249,300		

$\frac{1}{2}$ *hr. before high water*

Noctiluca miliaris	4,100		
Biddulphia sinensis	2,300	*Sagitta setosa*	2
Chaetoceros subtilis	1,050	*Caprella septentrionalis*	1
Lithodesmium undulatum	1,000		
Biddulphia mobiliensis	550		
Bellarochia malleus	500		
Rhizosolenia stolterfothii	50		
Copepod nauplii	300		
Centropages hamatus	150		
Total	10,000		

From the foregoing it will be seen that from 2 to 3 hr. before high water, when the tide is "making" at about 2 knots or more, the catch is heaviest (Fig. 3). This, in a measure, is what one would expect, the heavier catches being due largely to the greater efficiency of the net with the swifter tide. The

last haul, made just before the tide was stationary, captured very few organisms; the net floated listlessly in the water at first, and before the 10 min. (as allowed for the previous hauls) had elapsed, it hung vertically, in which position it would have remained for nearly ½ hr., that is, until the ebb carried it eastwards.

There do not appear to be any existing records of the distance covered by the tide in the Thames mouth. The investigations of the Port of London Authority have not been continued beyond Westcliff-on-Sea to the east. As near as one can estimate, however, the tide travels about 5 miles on the flood and about 7 with the ebb. Consequently, the water lying off Southend Pier at high water had been in the vicinity of the Nore Lightvessel 6 hr. previously. Conversely, the water from the Chapman Light, in Sea Reach, ebbs as far as Southend Pier (Fig. 1). The Chapman and the Nore Lights are some 11 miles apart; the average specific gravity of the water at the former is 1020 and at the latter 1022. The Thames at the Chapman Light is barely 4 miles wide, but from that point it widens rapidly until, at the Nore, it is quite 10 miles in width; a further 10 miles eastward finds the Estuary 40 miles across, to all intents and purposes open sea.

Slight as the difference in specific gravity may seem, it is sufficient to control, in great measure, the travels of many estuarine, and some planktonic, organisms. Immature herrings and sprats of the "whitebait", for example, do not journey beyond the Nore to the east and Gravesend to the west; although, two centuries ago, when pollution was less rife, whitebait could be captured as far up river as Blackwall. Before the Port of London Authority took matters in hand there was a possibility that the whitebait would be driven out of the Estuary altogether.

The limits of the plankton Crustacea are governed, largely, by winds, tides and currents. The Harpacticids, however, from their preference for such diatoms as live in the tangled masses of *Zostera*, are more protected, and, although quite a number occur in the plankton proper, for diversity of species and number of individuals, the weed-grown creeks are unequalled.

4. Notes on plankton species

(*a*) PHYTOPLANKTON

DIATOMS

With the exception of one haul, diatoms dominated the plankton numerically. The haul in question was made on the 3 May 1934, and contained a few scattered groups of *Bacillaria paradoxa* only, and this was the only occasion when Copepods predominated.

Biddulphia sinensis was the most prolific and persistent diatom, and, as it was present in nearly all the samples, it would seem that it is now permanently established in the Thames Estuary. *B. sinensis* is a comparatively recent

introduction to the North Sea, suddenly appearing there in 1903 (**2**), and is usually present in great abundance in the autumn along the eastern side of the Southern Bight. Between 1921 and 1932, it was only found sparingly along the western side (**4**), but following the hot summer of 1933 there was an ex-

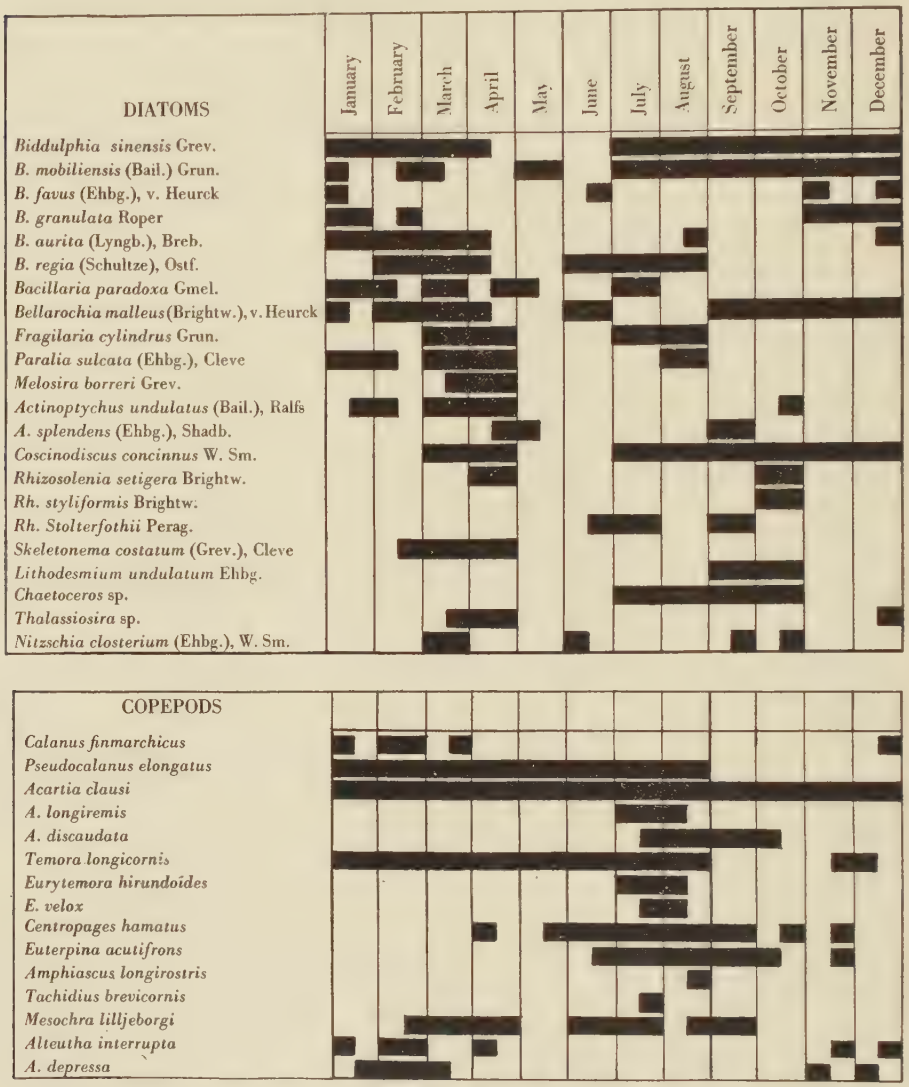

Fig. 4.

ceptionally big development of the diatom, and the concentration spread south-west (**5**). In the following year there were even larger numbers in the south-west. It seems probable that its presence in the Estuary is due to this cause. If this is so, the establishment of a new centre of distribution may have

some effect on the East Anglian autumn herring fishery, as it has been shown (**4**, **5**) that concentrations of diatoms off East Anglia in autumn can seriously affect the shoaling of the herring.

Next to *B. sinensis* in point of consistent profusion is *Bellarochia malleus*. *Skeletonema costatum*, during its brief appearance, was the most abundant, especially in the fine net.

The following tables may convey more clearly the actual diatom variation than if the various species were treated separately. See also Fig. 4.

The most abundant diatoms of each month in order of preponderance

January	February
Biddulphia aurita	*Biddulphia aurita*
Bellarochia malleus	*Bellarochia malleus*
Biddulphia sinensis	*Biddulphia sinensis*
Bacillaria paradoxa	*Bacillaria paradoxa*
Paralia sulcata	*Paralia sulcata*
Biddulphia granulata	*Gyrosigma angulatum*, var. *estuarii*
March	**April**
Biddulphia aurita	*Biddulphia aurita*
B. sinensis	*Bacillaria paradoxa*
Bellarochia malleus	*Skeletonema costatum*
Bacillaria paradoxa	*Fragilaria cylindrus*
Coscinodiscus concinnus	*Biddulphia sinensis*
Biddulphia mobiliensis	*Melosira borrerii*
May	**June**
Bacillaria paradoxa	*Bellarochia malleus*
Biddulphia sinensis	*Rhizosolenia stolterfothii*
Bellarochia malleus	*Biddulphia sinensis*
Fragilaria cylindrus	*B. favus*
	Gyrosigma angulatum, var. *estuarii*
July	**August**
Rhizosolenia stolterfothii	*Biddulphia sinensis*
Chaetoceros densus	*Fragilaria cylindrus*
Biddulphia sinensis	*Chaetoceros densus*
Fragilaria cylindrus	*Biddulphia mobiliensis*
Bacillaria paradoxa	*Paralia sulcata*
Coscinodiscus concinnus	*Coscinodiscus concinnus*
September	**October**
Biddulphia sinensis	*Biddulphia sinensis*
Bellarochia malleus	*Lithodesmium undulatum*
Biddulphia mobiliensis	*Biddulphia mobiliensis*
Lithodesmium undulatum	*Bellarochia malleus*
Chaetoceros subtilis	*Coscinodiscus concinnus*
Coscinodiscus concinnus	*Rhizosolenia styliformis*
November	**December**
Biddulphia sinensis	*Biddulphia sinensis*
Bacillaria paradoxa	*Bellarochia malleus*
Bellarochia malleus	*Bacillaria paradoxa*
Biddulphia mobiliensis	*Biddulphia granulata*
B. granulata	*Actinoptychus undulatus*
B. favus	*Biddulphia mobiliensis*

The following lists give the relative abundance of the various species. The first list relates to such diatoms as are persistently present in fairish numbers, or are exceptionally prolific in their season. The second to what one might call

occasional components, or to those that are consistent members of the plankton, albeit in small numbers. The third list contains the diatoms that were found sparsely, or on only one or two occasions.

Common

Biddulphia sinensis Grev., *B. mobiliensis* (Bail.), Grun., *B. granulata* Roper, *B. aurita* (Lyngb.), Bréb., *Coscinodiscus concinnus* W.Sm., *Bellarochia malleus* (Brightw.), v. Heurck, *Bacillaria paradoxa* Gmel., *Actinoptychus undulatus* (Bail.), Ralfs, *Melosira borreri* Grev., *Paralia sulcata* (Ehbg.), Cleve, *Fragilaria cylindrus* Grun., *Skeletonema costatum* (Grev.), Cleve, *Rhizosolenia stolterfothii* Pérag., *Lithodesmium undulatum* Ehbg., *Chaetoceros densus* Cleve.

Frequent

Biddulphia favus (Ehbg.), v. Heurck, *B. regia* (Schultze), Ostf., *Gyrosigma angulatum* W.Sm., *G. angulatum* var. *estuarii*, *Coscinodiscus marginatus* Ehbg., *C. excentricus* Ehbg., *C. nitidus* Greg., *C. sub-bulliens* Jörg., *Actinoptychus splendens* (Ehbg.), Shadb. *Nitzschia closterium* (Ehbg.), W.Sm., *Licmophora lyngbyei* (Kütz.), Grun. *Chaetoceros subtilis* Cleve, *Rhizosolenia styliformis* Brightw., *R. setigera* Brightw.

Infrequent

Guinardia flaccida (Castr.), Pérag., *Biddulphia rhombus* (Ehbg.), W.Sm., *B. alternans* (Bail.), v. Heurck, *Navicula granii* (Jörg.), *Eupodiscus argus* (Ehbg.), W.Sm., *Ditylium brightwelli* (West), Grun., *Rhizosolenia delicatula* Cleve, *Thalassiothrix frauenfeldii* (Grun.), Cleve & Grun., *Hyalodiscus stelliger* Bailey, *Nitzschia seriata* Cleve, *Thalassiosira hyalina* (Grun.), *T. nordenskioldii* Cleve.

The diatoms from the mud and *Zostera* masses of the adjacent creeks vary in great measure from those given above. To generalize, the creek diatoms are almost entirely Naviculoid, so also are those from the surface mud of the foreshore at Westcliff-on-Sea, the exception in the latter case being *Biddulphia favus* which is fairly common at times. The light surface sand of the cockle beds off Foulness Island contains similar diatoms plus some of the smaller *Coscinodiscus* species; it is this type of diatom that is found more commonly in the gut of the cockle (*Cardium edule* L.), and not those of the plankton of the same district.

(*b*) ZOOPLANKTON

RHIZOPODA

Polythalamia

Foraminifera were present in all samples in greater or lesser degree. With strong, scouring tides, 10% or more of the bulk of the samples would consist of Foraminifera. On the mud of the foreshore I found a fair number, mostly *Nonionina* sp.; on the beach at Foulness Point, and, in particular, along the edges of a tidal dyke behind the seawall, I found most of the types that occupied the plankton samples. These are enumerated below in the order of their preponderance.

Polystomella striato-punctata (F. & M.), *Miliolina* sp., *Biloculina* sp., *Nonionina* sp., *Planorbulina mediterranensis* d'Orb., *Lagena striata* (d'Orb.), *Textularia variabilis*.

Cystoflagellata.

Noctiluca miliaris Surir.

Although sporadic in appearance *Noctiluca* were present in at least one sample during the month throughout the year, usually in fairly great numbers. They did not appear only when the weather had been warm; for example, on 3 December 1933 during a bitterly cold easterly gale which had been blowing for some days, the catch included *Noctiluca* in proportionately large numbers. In August and September they were most abundant and in those months nearly all specimens observed contained the diatoms *Rhizosolenia stolterfothii* and *Paralia sulcata*. They were most prolific in the sample taken on 17 September 1934, when 84,000 were present.

Dinoflagellata

During the winter of 1933–4, when the 180-mesh Apstein net was in use, the following Dinoflagellates, averaging 500 of each species per haul, were identified.

Ceratium furca Ehbg.
C. fusus Ehbg.
C. tripos Nitzsch.
Ceratium macroceros Ehbg.
Peridinium depressum Bail.

CILIATA

Tintinnoidea

Tintinnopsis campanula (Ehr.) Dad.

Very few Tintinnids were found in the 60-mesh net, but during the time that the 180-mesh net was used large numbers were captured. Of the various species taken at one time or another the above was the only one that I could identify.

FLAGELLATA

Phaeocystis sp.

Phaeocystis usually appeared in the plankton in mid-May, as a faint trace, and increased until mid-August. By September, however, the water is quite clear. The whitebait, when *Phaeocystis* is in evidence, seek the creeks and the inshore water; in fact, during those months when it is at its height the whitebait fishermen pursue their calling from the beach itself by means of dragnets. This they have done for many years. The fishermen say that "'bacca juice" is always more prevalent after a mild March and April and also that if it is found early in the year then it will be very abundant and will remain longer in the Estuary.

COELENTERATA

Anthomedusae

Bougainvillea britannica Forbes.

One specimen only, 7 March 1934.

Sarsia tubulosa (Sars).

Two specimens, April 1934.

Podocoryne carnea Sars.

Scattered specimens (half a dozen in each haul) from March to May.

Rathkea octopunctata (M. Sars).

This species literally swarms in the Estuary from March to April at which times it occupies at least half of the bulk of the catch.

Leptomedusae

Obelia nigra E. T. Browne.

In fair numbers between January and March only.

Phialidium hemisphericum (Peron & Lesueur).

This is the most abundant of the Medusae between June and October. The largest catch was on 31 July 1934 when 240 were present.

Discomedusae

Aurelia aurita L., and *Cyanea capillata* L.

Young specimens, 4–10 mm. in length, were taken during early summer.

CTENOPHORA

Pleurobrachia pileus Flem.

Sporadically, and never more than six in one haul, between February and September.

ECHINODERMATA

Asteridae

Bipinnaria of *Asterias rubens* L.

A few were found in the summer hauls.

Echinopluteus of *Echinus miliaris* Leske.

This is the only member of the Echinidae found on the adjacent and extensive Maplin Sands. The pluteus is not common in the catch, although the spines, together with *Alcyonium* and sponge spicules, are a feature of hauls taken on strong tides.

CHAETOGNATHA

Sagitta setosa (J. Müller).

Present at all seasons.

Sagitta elegans (Verrill). Also a constant member of the plankton but in fewer numbers than *S. setosa*.

The occurrence of *Sagitta elegans* so close to the shore in the southern North Sea is at variance with the picture of the distribution of this species we should have expected from the work of F. S. Russell (**3**). As *S. elegans* is considered as an indicator of Atlantic water, the following records of its occurrence in the Thames Estuary might be of some interest:

1933. 20 November, 3 and 21 December.

1934. 5 and 25 January, 3 and 21 February, 7 and 27 March, 17 April, 17 September.

POLYCHAETA

Autolytus prolifer O. F. Müll.

Occasional specimens taken during the winter months.

Magelona sp.

Nectosome and post-larvae in September only.

Terebella sp.

Post-larval forms present at intervals throughout the year.

The various larval forms of Polychaetae are present in constant numbers throughout the year.

CRUSTACEA

Cirripedia

Balanus balanoides L.

Both the cypris and the nauplius larvae, as well as exuviations of the adult, were present in every sample throughout the year. Nevertheless, one week would find them abundant, another would find them sparse; but in no case could a reason be adduced for the variation.

Copepoda

Calanoidea

Calanus finmarchicus (Gunner).

On one occasion only were adults of this Copepod found (21 December 1933), 240 being present. Immature specimens, on the other hand, were a feature of the hauls during spring.

Pseudocalanus elongatus Boeck.

Except during the summer this species was fairly common, being present in numbers varying from 100 (1 June 1934) to 2000 (5 January 1934).

Centropages hamatus (Lilljeborg).

In late spring a sprinkling of immature specimens were found, by mid-summer the adults were present and remained in the plankton until October. In no instance did they dominate the Copepod content.

Temora longicornis (O. F. Müll.).

A steady population of this Copepod marked nearly all samples. Spring and autumn were the most prolific months when as many as 3000 specimens were found in one sample (17 April 1934).

Eurytemora hirundoides (Nordquist).

Found only during August and September, and then in but few numbers, in 1934. This applied also to the years 1935 and 1936. In 1937, however, a haul made in the first week of April captured 5500 specimens.

Eurytemora velox (Lilljeborg).

Although I did not find specimens of this species in the plankton samples taken from Southend Pier I have taken it, in September, in the Crouch Estuary off Burnham.

Acartia clausi Giesbrecht.

This is by far the most common Copepod in the Thames Estuary plankton, outnumbering, save in very few instances, the sum total of all the other species. It was present in every sample without exception.

Acartia longiremis (Lilljeborg).

Apparently this is solely a summer visitor; it was observed only during August and September when it was in the proportion of one to five of *A. clausi*.

Acartia discaudata (Giesbrecht).

Present in August and September only, but in greater numbers than the foregoing.

Harpacticidae

Longipedia coronata Claus.

A few specimens were obtained in September 1934.

Euterpina acutifrons (Dana).

Fairly common from February to October.

Amphiascus longirostris (Claus).

In quite large numbers in the sample of 27 August 1934 but not noticed in any others.

Tachidius brevicornis Lilljeborg.

On 31 July 1934 the haul contained 150 specimens.

Mesochra lilljeborgi Boeck.

Likewise a summer visitor.

Alteutha interrupta (Goodsir).

I have taken this, and the following Harpacticid, from the surface mud off Westcliff-on-Sea; on occasion during the winter and spring, specimens of both have been in the catch.

Alteutha depressa Baird.

If anything this species is more numerous than the last.

CLADOCERA

Podon intermedius Lilljeborg.

One specimen only was found and that on 27 August 1934.

AMPHIPODA

Gammarus locusta (L.).

Found in sparse numbers during spring.

Gammarus marinus Leach.

Found occasionally in spring and summer.

Gammarus duebeni Lilljeborg.

This was the most common of the Gammaroidea; even so, no sample contained more than five specimens. They were present at all seasons.

Paratylus swammerdami (Milne-Edwards).

One specimen, 17 September 1934.

Caprella linearis Spence Bate.

Very common from May to October.

Caprella septentrionalis Kröyer.

A few specimens were found in the hauls during October.

Phtisica acaudata (Gron.).

This Amphipod was represented in nearly every sample throughout the year. The greatest numbers were taken in September.

The following Amphipods, although not noticed in the samples taken from the end of Southend Pier, were present in hauls made in the Northern part of the Estuary:

Apherusa bispinosa (Spence Bate).
Dexamine spinosa (Mont.).
Aora typica Kroyer.
Corophium bonelli Milne-Edwards.
Unciola crenatipalmata Spence Bate.

ISOPODA

Idothea baltica (Pallas).

Sporadic, although fairly common in the catch during the summer months. Sixty specimens were present in the catch of 3 September 1934. Ordinarily they are frequently found in the nets of the local shrimpers and whitebaiters.

CUMACEA

Pseudocuma longicorne (Spence Bate).

An occasional specimen was to be found in the spring and summer hauls.

Pseudocuma similis G. O. Sars.

This species was fairly common during winter and spring.

MYSIDACEA

Gastrosaccus normani G. O. Sars.

A few specimens were found in several of the winter hauls.

Gastrosaccus sanctus (van Beneden).

Represented in the sample of 3 February 1934.

Gastrosaccus spinifer (Goës.).

One specimen only was found and that was on 3 May 1934.

Siriella clausi G. O. Sars.

Three individuals were in the sample of 31 July 1934.

Schistomysis ornata G. O. Sars and *S. spiritus* Norman.

These Mysids were in most of the samples taken during February, March, and April, but never exceeding ten specimens in any one sample.

Macropsis slabberi van Beneden.

This was by far the most common Mysid and was present in nearly every sample throughout the year; in the summer months as many as three or four hundred would be found in the net. The average length was 11 mm. and never exceeded 14 mm.

DECAPODA (MACRURA)

Crangon vulgaris L.

I had anticipated making consistently large hauls of the larvae of this shrimp throughout the year. In the summer the adults congregate in the warmer water of the swins and runnels close inshore, consequently one would not expect to find many individuals near the surface at a mile from the beach. On the other hand, as there are undoubtedly three (possibly more) breeding periods of *Crangon vulgaris* during the year, there should be many immature specimens in the deeper water such as obtains off Southend Pier. The older females bury themselves in the sand or mud of the sea-bed during cold weather but the males and the young remain between the bottom and mid-water. Moreover, as the tide retreats to within two or three hundred yards of the pier head, even in summer it would be natural to expect, at the least, a sprinkling of immature specimens at all seasons. The sum total of immature members of this particular species captured was one only and that on 7 February 1934, the length being 18 mm.

There is a possibility that a net with a coarser mesh would have met with a greater measure of success. Nevertheless, on occasion, an adult male, 25–35 mm. in length was captured and, as will be seen, a number of larval fishes, besides adults of *Leander squilla*. This seems to indicate that the fine mesh was not alone responsible for the paucity of specimens. Neither have I taken larval shrimps in the more seaward areas of the Estuary, i.e. the Blackwater—Crouch estuaries. From the foregoing I am inclined to think that *Crangon vulgaris* breeds and develops in the more brackish water, such as obtains between Holehaven and Gravesend; or, in any case, more so than off Leigh and Southend where the shrimp fishery has its headquarters.

Leander squilla L.

An occasional specimen of this prawn, locally known as the "white shrimp", was found during November and December but at no other time.

Palaemonetes varians (Leach).

No specimens were found in the samples taken off Southend Pier. Samples from the Crouch mouth contained adults and a very few larvae. In spring, however, the salting pools literally swarm with larvae of from 6 to 10 mm. in length. Strangely enough, although the adults will survive the transition from brackish water to a freshwater aquarium and will live for many months under such conditions, the larvae die in the course of a few hours.

DECAPODA (ANOMURA)

Porcellana longicornis L.

From the middle of August to the end of September the net contained from 10 to 50 megalopa larvae of this crab in the various hauls. Ordinarily the adult does not inhabit the north bank of the Estuary: the Kent side is more favoured, and the presence of these megalopae seems to suggest a mingling of currents in the vicinity of, say, the Mouse Lightvessel. Other organisms, such as larval molluscs, which do not come in the Essex fauna as adults, were found at times in the plankton in various stages of development.

DECAPODA (BRACHYURA)

Carcinus maenas Penn.

The zoea larvae of the common shore crab appear towards the end of March and occupy the plankton until July; by the end of August the megalopa take their place.

MOLLUSCA

LAMELLIBRANCHIATA

Pecten sp. juv.

From May until mid-summer specimens were present in the net, their numbers being greatest in May. Of the various species of *Pecten* inhabiting the Thames Estuary none is found in any abundance either to the north or west of the Nore Sand. An occasional individual may wander from its usual ground but, generally speaking, the principal scallop area does not start until the North Foreland has been rounded.

Cardium edule L.

From April until August larval cockles were present in great numbers, the peak period being mid-June. I have not seen the veliger stage at all.

Lamellibranch sp. var.

The larval stage of various other lamellibranchs are featured in early summer. *Mya*, *Tellina*, etc. are the principal genera represented.

GASTROPODA

Littorina littorea L. Ova.

From March until the end of August the ova of the common periwinkle were present in the haul, the two peaks being in the first week of March and the last week of June. With the exception of one haul which contained 60 specimens (27 November 1933) none were in the catches made between the end of August and the beginning of March. W. M. Tattersall (**6**) refers to the protracted breeding season of this Gastropod and there can be little doubt that, in the Thames Estuary in any case, the breeding season extends over at least six consecutive months. The veliger stage was noticed in the plankton during July and August principally, although in succeeding months a few were present.

TUNICATA

Oikopleura dioica Fol.

This Appendicularian was first noticed in the samples taken in May when 60 were found in one haul. The numbers gradually increased until on 9 October the net contained 1000. On 29 October 1934 their numbers fell off and after that date they were entirely absent.

FISHES

Syngnathus rostelatus Nilss.

This, the only adult fish found in the plankton, was first recorded from the Thames Estuary from specimens found in the sample of 20 November 1933. I am indebted to Dr J. R. Norman, British Museum (Natural History), for identifying the specimens.

Syngnathus acus L.

Immature specimens, closely resembling the adult *S. rostelatus*, were present during July and August.

Clupea sprattus L.

Between June and August 1934, a very few specimens (never more than three in any one haul) were present in the net. These varied in length from 6 to 9 mm.

Clupea pilchardus Walbaum.

Six specimens on 22 June 1934.

Clupea harengus L.

In March a fair number of immature herrings were in the plankton, the length being from 13 to 16 mm. Specimens taken in late April were very few and measured 15–17 mm. One specimen was taken 27 August 1934 and this was 21 mm.

Pleuronectes sp.

In March and April in most years small, immature flat fishes were in the catch. The length varied between 7 and 10 mm.

Leptocephalus morrisii Gmelin.

In March 1933 whilst trawling for shrimps off the Chapman light the trawl contained, among other things two specimens of *L. morrisii*, length 75 mm. They were alive when captured.

Fish ova, pelagic.

On 1 June 1934, the only fish egg was obtained, probably of the flounder, but I cannot be certain of this. Contrary to my expectations, eggs were disappointingly few. Numerous fishes with pelagic eggs breed within the precincts of the Estuary; that only one was found was surprising. However, at some future date, I hope to take samples from other parts of the Estuary with a view to obtaining some data on the breeding habits of such fishes as the sole, plaice, dab, herring, sprat, whiting and pilchard.

5. General inferences

The foregoing list of planktonic organisms shows a typical littoral flora and fauna. With a few exceptions the Inner Estuary, at least, seems to have nothing surprising to reveal. The exceptions, however, give one the impression that the Outer Estuary in the vicinity of, say, the Edinburgh and the Princes Channels to the south-east and the Wallet, the Middle, Black and Barrow Deeps to the north-east and, in particular, the Kentish Knock Light to the East, might exhibit less estuarine features. To the best of my knowledge these areas have yet to be examined thoroughly. Indeed, with the exception of Dr James Murie's report on the Thames Estuary Sea Fisheries (**1**), the Thames Estuary has been surprisingly neglected by zoologists. Of the four main fisheries of the district, viz. cockling, shrimping, spratting and whitebaiting, only spratting is not dependent on the plankton of the Estuary for its maintenance. It is true that if the decline in those fisheries locally is maintained, they will cease to exist within the next twenty years or so. At one time they were worth many thousands of pounds annually to the Leigh and Southend fishermen. There are several reasons for the decline, also there are not a few reasons why there should not be a decline—one cannot always lay the blame at the door of pollution.

The prescience of the fishermen regarding the whereabouts of his prospective catch at different seasons is truly astounding; nevertheless, the Outer Estuary is in great measure *terra incognita* to most of the present-day Leigh

fishermen. Yet there are fish to be caught in the more distant and deeper swins; the crew of one of the spratters for the past two seasons, after the spratting time was over, set out long lines in the Middle Swin with surprising results. The area in question, if it were better understood, could produce a fishery of miscellanea (sole, turbot, brill, etc.) that would pay better than the present fisheries do.

In all, including the sharks and rays, over 100 different species of fish have been captured at one time or another within the confines of the Estuary. Of this number, apart from whitebait and occasional Peter netting for plaice, sprats alone are fished for; these constitute, perhaps, one of the least profitable of fisheries.

The Inner Estuary is undoubtedly rich in food for small fry and this must have its repercussion as regards the food of larger organisms in the more seaward areas. For this reason alone, i.e. that of fostering an additional fishery, I feel that further research is necessary.

6. Acknowledgement

I would like to take this opportunity of conveying my thanks to the Director and to the plankton staff of the Fisheries Laboratory, Lowestoft, for the facilities they gave me for studying plankton at the Laboratory, and to the latter for their assistance in compiling this paper.

7. Summary

The results of a phyto- and zooplankton survey in the Thames Estuary from November 1933 to April 1937 are described. Most of the survey was done at Southend-on-Sea. In lesser degree the waters in the vicinity of Mersea and Burnham-on-Crouch were studied. The seasonal changes are analysed, with special reference to diatoms and Copepods, also the relation of plankton to the tides. The plankton of the Thames Estuary forms the principal food of the cockle, whitebait and the shrimp, all of which are fished extensively and are capable of greater development. There are large oyster beds, principally at Colchester and Whitstable; the oyster depends almost entirely on diatoms for its food.

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TEMPERATURE AND THE INCIDENCE OF CERTAIN SPECIES IN WESTERN EUROPEAN WATERS IN 1932–1934

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1. Introduction

In the course of an investigation into the relation between the quantity of brood in certain Lamellibranch Molluscs and weather conditions (Stephen, 1938), a well-marked rise in the value of the mean air temperature in certain areas for the years 1932–4 was noticed. These years were remarkable for the incursion into British waters of species which do not usually occur so far north, and also for the specially large broods recorded for several species.

So far little notice seems to have been taken of this period as a whole, although numerous isolated records of the unusual spread of various animals have been given. The object of these notes is to draw attention to the general course of events, and it is hoped that others may add to the records. Since the species affected were in several cases of economic value it is important that as complete a record of the period as possible should be made.

My thanks are due to Major A. H. R. Goldie of the Meteorological Office, Air Ministry, for supplying me with the figures for temperature.

2. Northward spread of organisms

The first evidence that animals usually found in more southern waters were entering British seas was contained in a letter to *Nature* (Kemp & Russell, 1932), where the appearance of *Velella*, *Ianthina* and *Salpa fusiformis* at Plymouth was recorded. Soon after (Stephen, 1932) it was reported that conditions were also abnormal in Scottish waters and, more especially, that whales and dolphins were more than usually common. Later it was reported (Farran, 1933) that the pelagic Tunicate, *Cyclosalpa bakeri*, a tropical form, had been taken 50 miles south-west of the Fastnet Light in August 1932; also that blue sharks (*Carcharinus glaucus*) were more than usually abundant. *Physalia*, *Velella* and *Ianthina* were also recorded as being abnormal in their distribution in New Zealand waters (Dakin, 1933).

Still more widely noted and of much more economic interest in certain countries, was the appearance of a disease of the eel-grass (*Zostera*) over wide areas. This disease seems to have spread very rapidly along the Atlantic coast of North America. It was first observed at the end of 1931 on the coast of Virginia. From there it spread north to Nova Scotia. In 1932 it was next met with on the coasts of Europe and spread to Denmark in 1932–3 (Petersen, 1935).

Coming more particularly to Scottish waters, a survey of the records shows that a similar invasion was taking place and that a number of species was concerned. Some appeared as late as 1935 so that the "invasion" was spread over a long period.

In the first place the number of whales and dolphins stranded on the Scottish coast (excluding the false killer, which is very erratic in its time of appearance and sometimes strands in shoals) while varying from year to year, is usually fairly low. In 1932, however, there was a sharp rise in the numbers stranded, showing that these animals were either more abundant or that the waters close to the Scottish coast were more favourable for them. The following were the numbers stranded:

1929	1930	1931	1932	1933	1934	1935
3	2	9	20	8	5	4

Three interesting species of fishes were noticed in Scottish waters during the same period. The long-finned tunny (*Thynnus germo*) whose only previous Scottish record was from Orkney in 1900, was taken twice during the period. The first record was from Lochgoilhead, Firth of Clyde, in 1933 (Stephen, 1933*a*), the second record from the Holy Loch, Firth of Clyde, in June 1934 (Stephen, 1934). In 1933 the saury pike (*Scombresox saurus*) invaded the Firth of Forth (Stephen, 1933*b*). This fish was also recorded from the Yorkshire coast in December 1932 and January 1933 (Clarke, 1933), and from the Isle of Man (Rept. Mar. Biol. Sta. Port Erin, 1933, p. 34). In April 1931 two specimens of the small shark, *Oxynotus paradoxus*, were taken 70 miles north-north-west of the Fastnet Light on the south-west coast of Ireland, this being the first record for British waters (Norman, 1932). The first and only recorded Scottish specimen was taken a year later in the Minch in March 1933 (Stephen, 1933*c*).

The pelagic Tunicate, *Cyclosalpa bakeri*, already reported as being taken on the south-west of Ireland (Farran, 1933), appeared in the Fair Isle passages and on the north of Scotland in November 1932 (Ann. Rep. Fish. Bd. Scotland, 1932, p. 68), this being the first Scottish record. The cuttlefish, *Sepia officinalis*, also invaded the North Sea in large numbers. In the Ann. Rep. Fish. Bd. Scotland, 1934, p. 54, it is reported as being present in the years 1932 and 1934. In 1934 it was very common, as may be judged from the report kindly given me by Mr J. Macpherson. He informed me that on one trip he was fishing in the area 90 miles east by north to 140 miles north-east by east from Aberdeen in depths from 60 to 80 fathoms and that he had taken about 200 on the trip. Up to ten were being taken in a 3 hr. haul with the trawl. He considered, however, that they had only been common for the last year or two. Specimens were also reported from Iona and from the Clyde, this latter being the first record of the species in the Millport area. Living *S. officinalis*, were also recorded for the first time from the Isle of Man, specimens being taken in September 1934. (Rep. Mar. Biol. Sta. Port Erin, 1934, p. 26). Another

cephalopod, *S. elegans*, was recorded for the first time from Scotland at Barra, in July 1935 (Forrest and others, 1936).

The pelagic Mollusc, *Ianthina britannica*, already mentioned as having been reported from Plymouth in 1932, appeared in large numbers on the west coast of Scotland in the summer of 1935 in Skye and in the Outer Hebrides (Beatson *et al.* 1936). In most cases it was accompanied by the Siphonophore, *Velella*, and the floating barnacle *Lepas fascicularis*. *Velella spirans* and *Noctiluca scintillans* occurred off the Isle of Man, having appeared in large numbers in October and July 1934, respectively. (Rep. Mar. Biol. Sta. Port Erin, 1934, p. 26).

An interesting series of records was given by Elmhirst (1936) showing the recent changes of the status of several species in the Clyde. Some species showed marked fluctuations during, or after, 1932. Since 1933 the summer invasions of the basking shark (*Selache maxima*) have been noticeable. Since 1932 also, there seems to be some evidence of the re-establishment of the once abundant bivalve, *Spisula subtruncata*. Young *Aplysia punctata* were present in large numbers in 1934. *Echinocardium cordatum*, scarce for a few years subsequent to 1920, became abundant again. Certain other species have become scarce in the area.

3. Production of brood

The amount of brood produced by certain species is also worthy of notice. In the southern North Sea an abundant herring brood appeared in 1932 (Hodgson, 1934, p. 63). This was a year before it was predicted and was a break in what appeared to be a definite 3-year cycle for this species. As against this successful herring brood, that of the haddock in Scottish waters was very poor for the 3 years 1932–4, that is during the period of high temperatures (Ann. Rep. Fish. Bd. Scotland, 1936, p. 61). In the Limfjord in Denmark, the oyster, which had not been known to spat since 1919 and was in danger of dying out, produced considerable spat in 1932 and 1934. Spärck (1935) attributes this to the high temperatures then prevailing.

In the Clyde area both *Tellina tenuis* and *T. fabula*, in which the incidence of broods has been closely studied since 1926, produced, in the autumn of 1932, broods several times in excess of any previously noted. Other species were observed to be breeding freely but were not studied quantitatively. There seems also to have been a large settlement of brood of *Mactra stultorum* off Montrose in 1933, to judge by the quantities of shells, measured and age estimated, which were washed up in the summers of 1934 and 1935.

4. Temperature correlations

As was to be expected from the increased air temperatures, the temperature of the surface waters in the North Sea was above normal. In the northern North Sea it was some 1·5–2° C. above normal in 1932. Salinities were also

high (Ann. Rep. Fish. Bd. Scotland 1932, p. 67; also Tait, 1935). In 1933 the temperatures were 2–3° C. higher. In the southern North Sea the same thing was found. In 1933 in the early part of the herring fishing season the temperature was about 2° C. above normal for that time of year (Hodgson, 1934, p. 103). These high temperatures seem to have been responsible for the growth of dense patches of diatoms which adversely affected the herring fishing by forming a barrier which was avoided by the migrating herring (Savage & Wimpenny, 1936).

The incursions of species already mentioned seem possibly to have been as much due to the favourable habitat caused by a general warming up of the northern Atlantic surface waters as by a greater northward flow of Atlantic water of southern origin, as already suggested by Farran, if one may judge from the higher air temperatures recorded from both sides of the Atlantic at the same time. These have been analysed for four stations, namely Florida, Rothesay, Lowestoft and Gaardbogaard, Denmark. The means for the whole year, and for the summer are shown in Table 1. Taking the temperature

Table 1

Temperatures in ° F.

(*a*) Yearly means

	1930	1931	1932	1933	1934	1935
Florida	74·6	74·2	75·9	76·0	75·3	74·9
Rothesay	47·3	47·1	48·0	48·7	48·8	47·8
Lowestoft	49·4	48·1	49·2	51·0	50·2	50·0
Gaardbogaard	46·5	43·8	45·7	45·9	47·2	45·4

(*b*) Means for April to September

	1930	1931	1932	1933	1934	1935
Florida	80·3	79·5	80·0	80·6	80·1	80·6
Rothesay	53·1	51·9	52·6	54·9	53·5	53·4
Lowestoft	55·9	54·5	55·8	57·9	56·6	56·6
Gaardbogaard	54·9	52·1	54·2	55·5	55·2	53·7

(*c*) Difference between successive yearly means

	1930–1	1931–2	1932–3	1933–4	1934–5
Florida	−0·4	+1·7	+0·1	−0·7	−0·4
Rothesay	−0·2	+0·9	+0·7	+0·1	−1·0
Lowestoft	−1·3	+1·1	+1·8	−0·8	−0·2
Gaardbogaard	−2·7	+1·9	+0·2	+1·3	−1·8

(*d*) Differences between successive summers

	1930–1	1931–2	1932–3	1933–4	1934–5
Florida	−0·8	+0·5	+0·6	−0·5	+0·5
Rothesay	−1·2	+0·7	+2·3	−1·4	−0·1
Lowestoft	−1·4	+1·3	+2·1	−1·3	0·0
Gaardbogaard	−2·8	+2·1	+1·3	−0·3	−1·5

gradients for the whole year (Table 1 (*c*)) it is seen that at all stations 1931 was colder than 1930, but in 1932 there was a rapid rise. 1933 was a little warmer than 1932, but by 1934 the temperature was falling at Florida and Lowestoft, and in 1935 there was a fall at all stations.

The same general course was followed by the summer temperatures (Table 1 (*d*)). 1931 was much colder than 1930, but the 1932 figures showed a considerable rise at all stations. This rise was even more marked in 1933.

There was a fall at all stations for 1934. The figures for 1935 showed little difference from those of the previous year.

That this "warming up" was a phenomenon of widespread incidence is further evidenced by the fact that the winter of 1933–4 in the Pacific north-west was unusually mild, the mean air temperature being 7·2° F. above the winter normal (Keyser, 1934).

One further point of interest arises. Mention has already been made of the incursion of *Velella* and other forms into New Zealand waters, recorded by Dakin, in 1933. The air temperatures for Dunedin N.Z. have been examined and it is of interest to see that they form a parallel with the conditions in other waters just described, only the rise started a year later and continued longer than in the north. The mean air temperatures were as follows:

1931	1932	1933	1934
50·5 F.	50·4 F.	51·3 F.	51·9 F.

5. Summary

Abnormally high temperatures in the Atlantic in the years 1932–4 were accompanied by unusual frequency and abnormal migration of certain marine animals, as deduced from records made round the coasts of the British Isles.

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PRODUCTION OF LARGE BROODS IN CERTAIN MARINE LAMELLIBRANCHS WITH A POSSIBLE RELATION TO WEATHER CONDITIONS

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(*With 6 Figures in the Text*)

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1. Introduction

In many species of animals it is only in certain years that there is a very large production of young, or at least of young which survive to form later, as a dominant year-group, a large proportion of the population. The problem of the underlying causes of these productive years is one of considerable economic importance. For example, it is now well known in fishes such as the haddock and the herring that successful broods are produced only at irregular intervals, and that such broods form the basis of the fishery for some years afterwards. So, too, with the small intertidal Lamellibranch Mollusc, *Tellina tenuis*, it is only in certain years that a successful spatfall occurs. Sampling of the population of this species in Kames Bay, Millport, begun in 1926, has been continued regularly. In that period there have only been four successful spatfalls, in the years 1926, 1930, 1933 and 1936 (Fig. 1).

It was thought possible that alterations in the physical conditions of the environment might be the chief causes of these variations in the quantity of brood. Since the annual shift of the modes has been about the same, even in the years with very large broods, it may be assumed that the food supply has always been sufficient. The species being an intertidal one, the chief variable physical factors affecting the environment are temperature, sunshine and rainfall. This paper deals principally with the fluctuations of these factors from

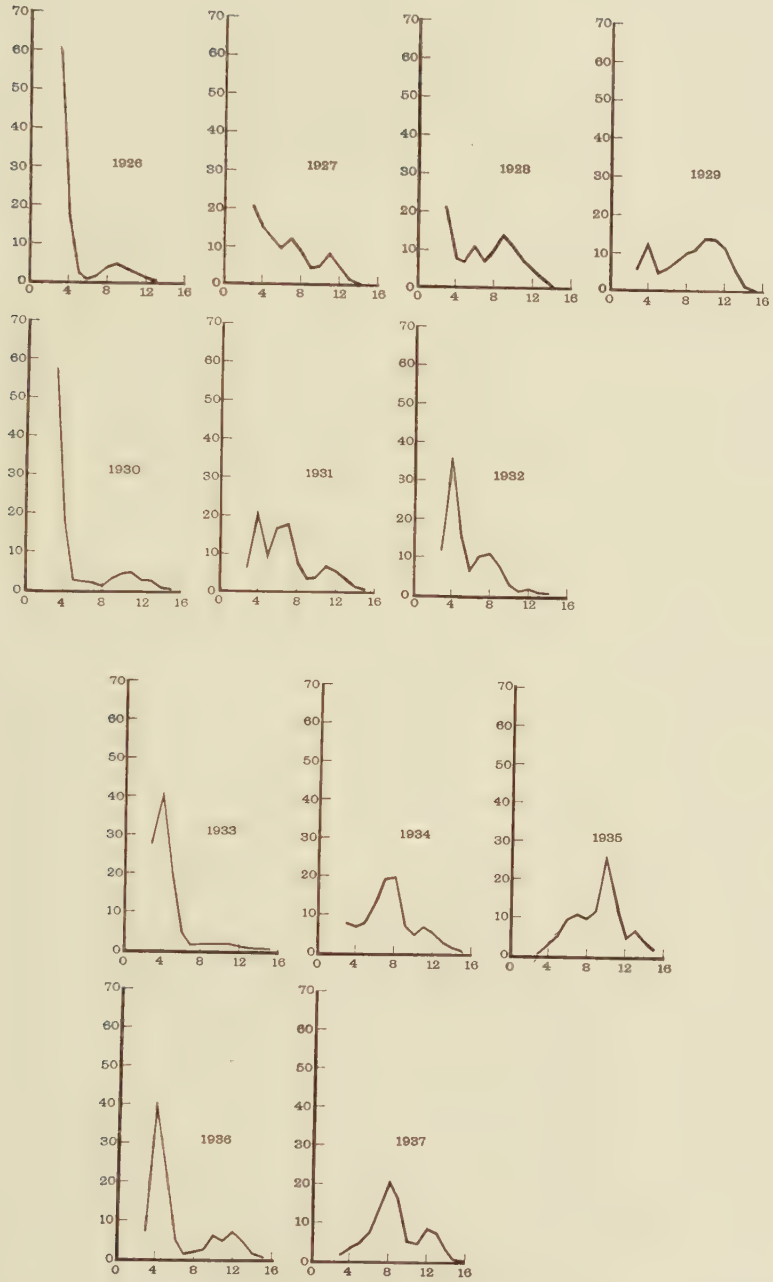

Fig. 1. Figure showing the size-frequency curves for the population of *Tellina tenuis* at low-water mark (station 5), Kames Bay, in the autumn of each year. *Ordinate*, % of total catch; *abscissa*, size in mm.

1925 to 1937 and their possible relation to the broods of *T. tenuis* in Kames Bay during the period. Observations have also been made on *T. fabula* in the same bay and the results are included for comparison with those of *T. tenuis*.

While the observations have been conducted since 1926 it is realized that a much longer period is necessary in such an investigation before thoroughly satisfactory comparisons can be drawn. Owing to the importance of the subject, however, it may be of general interest to summarize the relations so far observed and in the hope that other workers may be interested in testing out what, at the moment, seems to be a reasonable working hypothesis to account for the appearance of large successful broods, at least in intertidal Lamellibranchs.

My thanks are due to Major A. H. R. Goldie of the Meteorological Office, Air Ministry, for supplying me with the weather records and for his help in other ways; also to Mr R. Elmhirst, Director of the Millport Marine Biological Station, for his assistance during my visits to the station where most of this work was done.

2. *TELLINA TENUIS*

(*a*) *General observations*

The principal observations on the size, frequency and density of the population of *T. tenuis* have been carried out in Kames Bay, Millport, where set stations at 40 yd. intervals have been sampled regularly. These stations are numbered from 1 at high-water mark to 5 at low-water mark, and 7 in $2\frac{1}{2}$ fathoms. At low water of spring tides an intertidal area of about 160 yd. in width is exposed. The sand therein is very fine and its texture and water-content is practically the same at all levels.

T. tenuis abounds in the bay, especially at station 5 where the principal observations have been made. This station lies in the centre of the bay at low-water mark of spring tides. The bay has rocks on each side cutting it off from the adjacent sands so that it is a more or less self-contained area. Its extent is thus limited and the spatfalls can be traced fairly easily. This is not the case on the Hunterston sands on the Ayrshire coast opposite, where *T. tenuis* also occurs. But here, owing to the fact that the sands are a mile or more in extent, the spat may settle in different places in different years and a long series of samples would have to be taken to make an accurate estimate of the conditions of the spatfalls. The length of time which could be devoted to sampling in any one year has not been sufficient to cover adequately this area and no attempt is made to compare it with Kames Bay.

At the beginning of the investigation samples were taken at regular intervals during the year; but after some knowledge of the biology of the species had been gained it was seen that this was not necessary, and samples have latterly been taken only in the autumn of each year. On each occasion the same procedure has been adopted. A square of sand with sides 0·5 m. has been marked

out and dug out to a depth of 15 cm., the sand then being run through a sieve with circular perforations 2 mm. in diameter. The measurement of *Tellina* used has been the greatest length, measured to the mm. above. As a rule additional control samples with a finer mesh were taken to ensure that the main collection was an accurate sample of the population.

(*b*) *General history of the population during the period*

The size-frequency curves and the summaries given here refer to the state of the population and the amount of spat in the autumn of each year at station 5 (Fig. 1).

Table 1. *Showing the actual numbers and percentages of the population of* Tellina tenuis *at each mm. length at station* 5, *Kames Bay, Millport, in the autumn of each year*

Actual numbers

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total measured
24 Sept. 1926	508	148	21	5	14	33	39	25	18	8	3	.	.	.	.	822
7 Oct. 1927	158	114	92	71	91	66	31	36	59	34	10	2	.	.	.	764
*28 Sept. 1928	313	114	102	159	103	143	199	159	106	75	38	5	3	.	.	1519
*20 Sept. 1929	59	114	46	53	77	97	104	137	136	112	56	17	4	.	.	1012
27 Aug. 1930	616	197	23	21	19	10	31	43	45	26	24	10	3	.	.	1068
14 Oct. 1931	39	121	56	105	111	45	20	24	39	33	21	8	5	.	.	627
*30 Sept. 1932	56	158	70	29	47	50	35	12	4	5	2	1	.	.	.	469
*3 Oct. 1933	1147	1597	798	178	47	57	65	66	58	42	30	13	7	1	1	4107
24 Oct. 34	64	57	66	111	162	166	60	38	54	43	25	10	4	.	.	860
16 Oct. 1935	1	11	21	39	43	39	47	102	51	19	26	16	8	.	.	423
2 Sept. 1936	84	419	244	55	12	17	24	64	50	77	50	15	2	.	.	1113
4 Oct. 1937	22	40	55	85	158	229	188	62	55	94	87	37	9	3	1	1125

Percentages

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
24 Sept. 1926	61·8	17·9	2·5	0·6	1·7	3·9	4·6	3·1	2·2	1·0	0·4	.	.	.	.
7 Oct. 1927	20·7	14·9	12·0	9·3	11·9	8·7	4·1	4·7	7·7	4·5	1·3	0·3	.	.	.
28 Sept. 1928	20·6	7·5	6·7	10·4	6·8	9·4	13·1	10·5	7·0	4·9	2·5	0·3	0·2	.	.
20 Sept. 1929	5·8	11·3	4·6	5·3	7·6	9·6	10·3	13·5	13·4	11·1	5·5	1·7	0·4	.	.
27 Aug. 1930	57·7	18·4	2·2	2·0	1·8	0·9	2·9	4·0	4·1	2·4	2·3	0·9	0·3	.	.
14 Oct. 1931	6·2	19·3	8·9	16·7	17·7	7·2	3·2	3·8	6·2	5·2	3·3	1·3	0·8	.	.
30 Sept. 1932	11·9	33·7	14·9	6·2	10·0	10·6	7·2	2·6	0·9	1·1	0·4	0·2	.	.	.
3 Oct. 1933	27·9	38·9	19·4	4·3	1·1	1·4	1·6	1·6	1·4	1·0	0·8	0·3	0·2	.	.
24 Oct. 1934	7·4	6·6	7·7	12·9	18·8	19·3	7·0	4·4	6·3	5·0	2·9	1·2	0·5	.	.
16 Oct. 1935	0·2	2·6	5·0	9·2	10·2	9·2	11·2	24·2	12·0	4·5	6·1	3·8	1·9	.	.
2 Sept. 1936	7·5	37·7	21·9	4·9	1·0	1·5	2·1	5·7	4·5	6·9	4·5	1·3	0·2	.	.
4 Oct. 1937	1·9	3·6	4·9	7·6	14·0	20·4	16·7	5·5	4·9	8·3	7·7	3·3	0·8	0·3	0·1

* These figures are for 2 × 0·25 sq. m. In other years the figures are for 0·25 sq. m.

1926. In this year there was a very large amount of brood present on the ground when the samples were taken in September. The brood made up over 60% of the population and had a mode of 3 mm. There was only one other group showing in the graph, namely, an older one with a mode of 9 mm. In the light of later work it is believed that this was derived from the spat of 1924.

1927. On the graph for this year there were three year-groups showing, namely, the new 1927 brood with the mode at 3 mm., the 1926 brood with the mode at 7 mm., and the 1924 brood with the mode at 11 mm.

1928. On this graph, again, three year-groups were showing, namely, the new 1928 brood with the mode at 3 mm., the 1927 brood with the mode at 6 mm., and the 1926 brood with

the mode at 9 mm., and now quite evidently the dominant year-group. The 1924 brood had now almost, if not entirely, died out.

1929. On this graph only two groups were showing, namely a small one, the new 1929 brood with the mode at 4 mm., and a larger one with the mode at 10–11 mm. This latter is very largely derived from the 1926 brood, but the 1927 brood accounts for the irregularity at about 8 mm. on the graph.

1930. In this year there were again only two groups showing, and the size-frequency curve is almost an exact replica of that of 1926. As in that year the population consisted very largely of the new broods, in this case the 1930 brood, while the year-group derived from 1926 and 1927 spats formed a small group from 8 to 14 mm.

1931. In this year there were three groups in evidence, namely, the new 1931 brood showing as a small group with the mode at 4 mm., the 1930 brood with the mode at 7 mm., and numerically the most important group; and finally the group with the mode at 11 mm. comprising the older year-groups, largely the remains of the 1926 brood.

1932. The principal feature of this curve is the presence of the new large brood, the 1932 brood, with the mode at 4 mm. The next year-group, with mode at 8 mm., has been derived from the 1930 brood and possibly to a very small extent from the 1931 brood, for the 1931 brood seems to have very largely died out. The third group with the mode at 12 mm. is very small and is the last remnants of the year-groups older than 1930.

1933. Again the principal feature of this graph is the large and dominating year-group made up of the new 1933 brood with the mode at 4 mm. The only other group showing is the very small one spreading from 7 to 11 mm., all that is left of the older year-groups.

A comparison of this graph with that of the previous year is very instructive, for it would seem that the large and dominant spats of 1930 and 1931 had almost entirely died out or been eaten out. Another point of interest is that the actual amount of this 1933 spat was by far the largest so far met with and averaged over 1600 per 0·25 sq. m.

1934. The new 1934 brood was very small in amount and the dominant year-group, with mode at 8 mm., was that derived from the rich 1933 brood. The older year-group with mode at 11 mm. mainly derived from the 1930 brood was not very large.

1935. On this graph the 1933 brood still survived as the dominant year-group, with mode at 10 mm. The 1935 brood does not seem to have survived at all since only about a couple of dozen individuals could be referred to it. The 1930 brood still shows as a small group with the mode at 13 mm.

1936. The dominant year-group is the 1936 brood with the mode at 4 mm. The fact that no brood was found in 1935 is reflected in the absence of a definite mode at 7 mm. where this group might have been expected to show. The older year-groups have become very much reduced in numbers, being less than half as numerous as they were in the previous year. There are two other year-groups with modes at 10 and 13 mm. derived from the 1933 and 1932 broods respectively.

1937. There was comparatively little brood on the ground in the autumn of 1937, and the dominant year-group was that with mode at 8 mm., very largely derived from the 1936 brood. The survivors of the broods previous to 1936 still formed a not inconsiderable part of the population being represented by the group with mode at 12 mm.

Thus while there was a certain amount of spat laid down every year at station 5 the years 1926, 1930, 1933 and 1936 stand out as vintage years in which it was not only very much larger in amount than usual but also survived to form dominant year-groups at a later period. It is noticeable that while the 1926 brood survived till its fourth year before being followed by a large new brood, the broods of the years 1930 and 1933 each survived only three summers

before this happened. As will be shown later, the most probable explanation lies in the temperature-values during the period.

(c) *Relation of spatfall to temperature*

There are numerous references in literature to the relationships existing between the spawning of marine animals and temperature, but no attempt seems to have been made to correlate the two over a long period. The ideal temperature readings for such a study of *T. tenuis* would be readings taken at the station where the samples were collected. It was not possible to obtain such a series of readings since only occasional visits could be paid to Millport; neither is a complete set of the local sea temperatures covering the whole period available. This is not so serious a matter as it at first sight seems. Since the position of the station is in the intertidal area the temperatures there will follow very closely the local air temperatures. A complete set of these is available from the meteorological station near Rothesay, a distance from Kames Bay of about six miles as the crow flies.

Table 2. *Table showing the deviations, from the means of the period* 1881–1915, *of the monthly mean air temperatures at Rothesay. The last line of figures is the algebraic sum of the means for the period April to September in each year*

	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Jan.	+2·9	+1·6	+1·0	+1·6	−2·5	+1·4	−0·6	+4·3	−0·9	+2·5	+2·2	−1·3	+2·0
Feb.	−0·3	+1·6	+1·0	+1·2	−4·6	−3·1	−1·1	+1·8	−0·3	+2·6	+1·2	−1·6	−0·4
Mar.	+0·3	+1·4	+2·0	−0·2	+2·2	−1·3	−2·6	+0·8	+2·9	−1·0	+2·4	+2·2	−3·6
Apr.	−1·8	+1·6	−1·6	−0·6	−2·6	0·0	−1·0	−3·0	+1·4	−1·6	+0·2	−1·2	+1·2
May	−0·9	−2·2	−0·9	−0·1	−0·3	−0·3	−0·5	−1·2	+0·3	−1·5	+0·3	+0·5	+1·4
June	+0·8	−0·8	−5·1	−4·6	−2·1	−0·1	−3·6	+1·1	+1·5	+0·7	−0·9	+0·3	−1·7
July	+0·8	+1·8	+0·6	−3·0	−1·0	−1·0	−1·4	−0·6	+2·4	+3·1	+0·5	−0·4	−1·0
Aug.	+0·2	+1·0	+0·6	−0·8	−1·5	−0·4	−1·1	+0·6	+1·2	−0·8	+1·3	+0·8	+1·3
Sept.	−3·1	+0·3	−1·8	−1·5	+1·4	−0·1	−1·7	−1·5	+2·3	+0·5	−0·2	+1·8	−0·2
Oct.	+1·1	−3·5	+1·5	+0·5	−1·1	+0·1	−0·3	−1·9	+0·9	+0·3	−0·3	+1·5	+0·7
Nov.	−2·2	−1·1	−0·4	+1·1	+1·1	−1·9	+2·3	+0·2	−0·5	+0·1	+0·1	−0·1	−0·1
Dec.	−2·5	+1·5	−2·9	−0·1	+1·7	+0·7	+3·1	+2·3	−0·4	+4·9	−2·2	+2·1	−1·9
	−4·0	+1·7	−8·2	−10·6	−6·1	−1·9	−9·3	−4·6	+9·1	+0·4	+1·2	+1·8	+1·0

For the purposes of this study of the relation of the growth and spatfalls of *T. tenuis* to temperature, several sets of figures may be used. One may use the actual daily temperatures, the monthly means, or, as has been done here, the deviations of the monthly means from a standard set of means (Table 2). The reason for using these figures is to draw a distinction between fluctuations from year to year in colder and warmer periods. By using the deviations from a standard set of means these differences can be given their proper relative values. The algebraic sum of the deviations of the monthly means from the standard means will show at a glance if any year or part of a year has been warmer or colder than normal. In this account the algebraic sum of the deviations for the period April to September is used, since that is the period of the year at Millport during which *T. tenuis* breeds and grows. The figures for the whole year may equally well be used and show the same general features.

The standard means used in the Meteorological Office for the period from 1925 to 1933 inclusive are based on the figures for the period 1881–1915. Those for the period 1934 onwards are based on the figures for the years 1901–30. As is evident, a uniform set of figures is necessary for our purpose. The deviations in the table for the years from 1934 onwards are those calculated to the means used in the first part of the table, namely those based on the years 1881–1915.

For convenience in the wording of the following paragraphs the algebraic sum of the deviations from the mean in the various tables for temperature, sunshine and rainfall respectively will be referred to as *St*, *Ss* and *Sr*.

St for the months, April to September, for the period 1925–36 is shown graphically in Fig. 2. This graph shows that the general conditions were as follows.

Fig. 2. Figure showing the variations in *St* (the algebraic sum of the deviations of the monthly means of the air temperature from the means of the period 1881–1915) at Rothesay from April to September for the years 1925–37. *Ordinate*, value for *St*; *abscissa*, year.

In 1925 *St* was a fairly low negative value, −4·0, but rose very considerably in 1926 to a positive value, +1·7. In 1927 it fell to −8·2 and in 1928 still lower to −10·6. It rose again in 1929 to −6·1, and still further to −1·9 in 1930. It fell again in 1931 to −9·3 but after that there was a rapid and continuous rise until the peak, +9·1, was reached in 1933. There was a considerable fall in 1934 to +0·4, but after that the figures have been fairly steady being +1·2 in 1935, +1·8 in 1936, and 1·0 in 1937.

Every year a certain amount of brood is found; but in the years intervening between the large broods it has been very much smaller and subject to a heavy mortality.

There seems to be a fairly close connexion between the quantity of the year's brood and the fluctuations in *St*. If, for example, Fig. 3 which shows the actual amount of brood per 0·25 sq. m. in September of each year be compared

with Fig. 2, showing the variation in *St*, it will be seen that the two graphs are very similar indeed. The only discrepancy between the two lies in the figures for 1934 and 1935. A partial explanation of this will be given later.

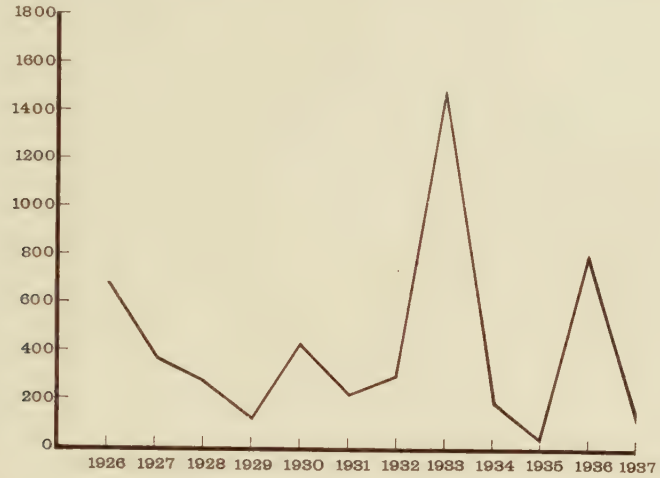

Fig. 3. Figure showing the variations in the actual amount of brood per 0·25 sq. m. in the autumn of each year at low-water mark (station 5), Kames Bay, Millport. *Ordinate*, number of specimens; *abscissa*, year of capture.

Further, the actual extent of the rise in *St* seems to have determined the size of the important broods in 1926, 1930 and 1933. Taking the rise of *St* in 1933 as the basis for temperature and the numbers of brood per 0·25 sq. m. in 1933 as the basis of brood, then the rise in *St* in 1926, 1930 and 1933 is proportional to the quantity of spat produced in these years as shown by the figures below.

Year	No. of spat	%	Rise in *St*	%
1926	675	41	5·7	42
1930	419	25	4·2	31
1933	1660	100	13·7	100

For Lamellibranchs, at least, there is a critical temperature below which a species will not breed. For the American Oyster it is 20° C. (Nelson, 1928). For the European oyster it is 18–20° C. (Spärck, 1935). For the cockle it is 15–16° C. (Orton, 1920). Spärck considers that the large spatfalls of the oyster in Denmark in 1932 and 1934 were due to high temperatures, the average temperatures at Aalborg and Oddesund in July of these years being 17·4 and 18·7° C., and 18·9 and 19·5° C. respectively. These temperatures are somewhat higher than the average temperatures for the Limfjord and approach the temperature of 18–20° C. which is necessary for a considerable renewal of the oyster population. Further, he remarks that if past experience is repeated, this fishery may be renewed for a period, but cannot be expected to last long. If the spatfalls of *T. tenuis* are related to *St*, as I have tried to show that they are,

then for the oyster, too, in all probability until *St* in their locality attains again to a favourable level so long will the oyster spat remain small in amount.

The critical temperature for *T. tenuis* has not yet been determined, but it is noticeable that in the years of the large broods, namely 1926, 1930, 1933 and 1936 *St* approached or went a little above the zero line, Fig. 2. A narrow band lying between +2 and −2 would cover the years 1926, 1930 and 1936. At what point exactly the temperature at the time of spatfall should be marked on the *St* line for 1933 is not now possible to determine, but it probably fell within this band or taking account of the large production of brood just a little above it.

One question arises: if the spatting of *T. tenuis* is conditioned by *St* why was there no large brood in 1934 and 1935, when *St* was at a level which gave a plentiful brood in other years? During the period this has been of two different forms. From 1925 till 1934 it has shown a series of sharp rises and falls; from 1934 till 1937 it has been rather flat and with no very marked variations. During the first period there were three well-defined peaks and these corresponded to the three large broods of *T. tenuis* already mentioned. During the second period there has been one large brood. The correlation during the first period between the position of the peaks on the curve for *St* and the large broods of *Tellina* seem too good to have been the result of coincidence. The appearance of a large brood during the second period where no sharp rise occurred shows that the relationship is still not fully understood, but it is hoped that a further series of observations may throw light on the matter. It is rather remarkable that in spite of the high level of *St* during the period 1935–7, that is in the years before and after the large brood of 1936, that the actual quantity of brood should have been as low as at any time during the whole range of observations.

(*d*) *Relation of spatfall to sunshine*

No records of sunshine are taken at Millport, but figures are available for the total hours of bright sunshine at Rothesay. The deviations of the monthly totals from the means of the period 1914–30 have been obtained from the Meteorological Office and are shown in Table 3. The algebraic sums of these deviations for the months from April to September are shown in Fig. 4.

From this graph it is seen that *Ss* was positive in the years 1925–27, being +34·0, +60·5 and +25·8 respectively, but fell to −44·4 in 1928. It rose again to +48·1 in 1929 but fell to −71·4 in 1930 and to the lowest figure for the period, −180·5 in 1931. From then it rose steadily, becoming positive again in 1935, but since then has been falling. From these figures there would seem to be practically no correlation between the variations in bright sunshine and the spatfalls of *T. tenuis*. The possible exception is the year 1931 when not only was it very sunless, Fig. 5, but also very cold (Figs. 2 and 3). In that year there seems to have been a heavy mortality, especially amongst the young brood which at first was fairly abundant.

Table 3. *Table showing the deviations of the total hours of bright sunshine at Rothesay from the means of the period* 1914–30. *The last line of figures is the algebraic sum of the means for the period April to September in each year*

	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
Jan.	−16·8	− 8·7	− 3·0	+ 8·5	+21·6	− 3·1	+11·6	+ 3·2	+15·9	+ 4·4	+10·9	+ 9·3	− 8
Feb.	−10·8	−14·2	− 7·0	+15·3	− 6·2	+18·8	+ 2·9	+44·1	+25·3	+13·2	+ 8·0	+ 9·1	+19
Mar.	+17·8	−42·1	+16·6	−43·8	+69·8	−17·7	+ 7·5	− 4·3	0·0	−16·8	− 9·3	−64·8	+16
Apr.	+16·8	−28·4	− 3·9	− 8·7	+ 8·5	− 6·9	−21·2	+ 4·0	−62·5	−27·4	− 2·0	−34·5	−87
May	−48·8	− 5·6	+46·1	+22·1	+45·1	+18·8	−16·1	+ 0·3	−34·1	−36·1	+91·4	+16·1	+37
June	+76·6	+ 1·4	+ 1·8	−21·6	+28·1	− 0·2	−99·0	+ 8·6	− 9·3	− 2·2	−54·9	+19·9	−25
July	− 5·5	+51·5	−15·3	−49·1	+ 0·5	−36·8	−76·4	−53·0	− 6·3	+65·5	+42·9	− 5·3	−20
Aug.	−28·9	+29·1	+ 9·8	− 4·8	−26·8	−19·0	+53·0	−24·1	+ 7·9	−24·9	− 7·9	−13·0	+10
Sept.	+23·8	+12·5	−12·7	+17·7	− 7·3	−27·3	−20·8	− 8·4	+50·6	0·0	−13·5	−22·9	+ 8
Oct.	− 1·8	+17·0	+10·7	−12·1	+ 0·8	−19·4	+ 6·7	− 4·6	−23·5	−23·6	−24·5	+ 8·6	0
Nov.	+25·9	0·0	+ 5·3	+ 4·2	−13·8	+ 5·0	−22·2	−11·7	+ 0·1	+ 4·6	− 8·1	−15·6	− 3
Dec.	+ 3·9	+ 1·8	− 0·2	+ 2·9	+ 5·8	− 4·8	−20·2	+ 0·4	−15·4	−26·9	+15·7	−28·8	+11
	+34·0	+60·5	+25·8	−44·4	+48·1	−71·4	−180·5	−72·6	−53·7	−25·1	+56·0	−39·7	−77

Fig. 4. Figure showing the variations in *Ss* (the algebraic sum of the deviations of the monthly total hours of bright sunshine from the means of the period 1914–30) at Rothesay from April to September for the years 1925–37. *Ordinate,* value for *Ss*; *abscissa,* year.

Fig. 5. Figure showing the variations in *Sr* (deviations of the monthly totals of rainfall from the means of the period 1925–35) at Millport from April to September for the years 1925–36. *Ordinate,* value for *Sr*; *abscissa,* year.

(*e*) *Relation of spatfall to rainfall*

Readings of the local rainfall are taken at the Millport Station and for the purposes of this paragraph the monthly totals in inches have been used. No figures for standard monthly means are issued by the Meteorological Office, so the means for the years 1925–35 have been calculated. The deviations of the monthly totals from these means are shown in Table 4 and the algebraic sum of the deviations for the months April to September are shown graphically in Fig. 5. An examination of these shows that there is no correlation between the local rainfall and the fluctuations in the amounts of the broods of *T. tenuis*. In the years of the big broods, for example, 1926, 1930, 1933 and 1936, while *Sr* was almost at zero in 1926 and 1936 and but little above it in 1930 it was actually at its lowest value in 1933.

Table 4. *Table showing the deviations of the monthly totals of rainfall in inches at Millport from the means of the period* 1925–35. *The last line of figures is the algebraic sum of the means for the period April to September in each year*

	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
Jan.	−0·59	+1·40	+1·22	+4·58	−3·47	−0·04	−0·49	+0·66	−0·93	−0·10	−2·21	−1·50
Feb.	+0·89	+1·82	−0·15	+1·47	−0·30	−2·50	+1·19	−2·72	+0·21	−2·36	+2·47	−0·77
Mar.	−0·56	+0·78	+1·47	+1·98	−1·15	−0·04	−1·47	−0·05	−0·47	−0·22	−0·29	+0·69
Apr.	+2·82	−0·32	+0·40	−1·03	−1·63	−0·47	−0·78	+1·30	−0·65	−0·05	+0·37	−1·22
May	+3·51	−0·15	−0·15	−1·55	+0·79	−0·62	+0·89	−0·70	−0·30	+0·25	−2·01	−0·15
June	−2·23	−0·01	+2·17	+0·93	−0·14	+0·20	+1·13	−1·21	−0·52	−0·47	+0·11	−1·28
July	−0·97	−0·27	+0·63	−0·87	+0·21	−0·31	+0·94	+0·50	+0·91	−0·02	−0·73	+2·68
Aug.	+0·30	+0·50	+0·07	−0·41	+2·43	+1·97	−2·72	−0·14	+0·01	−0·24	−1·82	−0·30
Sept.	−0·01	+0·08	+2·33	−0·16	−2·17	+0·04	−2·20	+0·56	−2·82	+2·03	+2·38	+0·47
Oct.	−1·52	+0·88	−1·48	+2·90	−0·65	+0·43	−2·12	+0·19	−2·97	+0·85	+3·52	−1·06
Nov.	−3·41	+2·45	+0·51	+1·48	+2·46	+0·31	+2·73	−1·15	−1·73	−3·71	+0·55	−1·62
Dec.	−1·73	−2·35	−3·72	−0·28	+6·53	+0·78	+0·70	+2·53	−2·83	+3·23	−1·41	+1·91
	+3·42	−0·17	+5·05	−3·19	−0·51	+0·81	−2·74	−0·99	−3·37	+1·50	−1·70	+0·20

3. *Tellina fabula*

Relation of spatfall to temperature

This species is also common in Kames Bay where it lives in the sandy area extending from close to low-water mark of spring tides out to the middle of the bay. Samples have been taken in September of most years since 1926, the station worked being about 50 yd. seawards of station 5 where the depth is $2\frac{1}{2}$ fathoms. The size-frequency curves for these collections are shown in Table 5, Fig. 6, for comparison with those of *T. tenuis*. It must be remembered, however, that not quite the same reliance can be placed on them for giving an accurate sample of the population, and that for two reasons. In the first place the collections were taken with a dredge and one cannot be quite certain that all the older and larger individuals were captured, some may have been below the working level of the dredge. In the second place Kames Bay is a feeding ground for several species of fishes, and examinations of stomach contents has shown that *Tellina* is consumed in quantity. This will reduce the

Table 5. *Showing the actual numbers and percentages of the population of* T. fabula *at each mm. length at stations* 6 *and* 7, *Kames Bay, Millport, in the autumn of each year*

Actual numbers

	3	4	5	6	7	8	9	10	11	12	13	14	Total measured
*2 Feb. 1931	83	691	424	90	17	4	22	16	3	3	.	.	1353
28 Oct. 1931	5	54	103	54	68	138	86	23	8	6	1	.	546
1 Oct. 1932	1	4	15	5	4	3	12	26	16	8	2	.	96
4 Oct. 1933	131	632	526	89	17	10	18	39	49	14	3	1	1529
24 Oct. 1934	30	55	8	3	17	28	29	4	9	6	1	.	190
23 Sept. 1935	117	392	179	28	3	3	12	12	13	4	.	.	763
5 Sept. 1936	6	65	17	8	17	24	32	18	21	7	2	.	217
4 Oct. 1937	44	30	17	10	10	25	50	51	31	33	11	1	313

Percentages

	3	4	5	6	7	8	9	10	11	12	13	14
*2 Feb. 1931	6·1	50·7	31·1	6·6	1·2	0·3	1·6	1·2	0·9	0·2	.	.
28 Oct. 1931	0·9	9·9	18·9	9·9	12·4	25·2	15·7	4·2	1·5	1·1	0·2	.
1 Oct. 1932	1·0	4·2	15·6	5·2	4·2	3·1	12·5	27·1	16·6	8·3	2·1	.
4 Oct. 1933	8·6	41·3	34·4	5·8	1·1	0·7	1·2	2·6	3·2	0·9	0·2	.
24 Oct. 1934	15·6	29·0	4·2	1·6	9·0	14·7	15·3	2·1	4·7	3·2	0·5	.
23 Sept. 1935	15·3	51·3	23·4	3·7	0·4	0·4	1·6	1·6	1·7	0·5	.	.
5 Sept. 1936	2·8	29·9	7·8	3·7	7·9	11·0	14·7	8·3	9·7	3·2	0·9	.
4 Oct. 1937	14·0	9·6	5·4	3·2	3·2	8·0	16·0	16·3	9·8	10·5	3·5	0·3

* Since there is no growth over the winter months these figures are taken as representing the autumn collection of 1930.

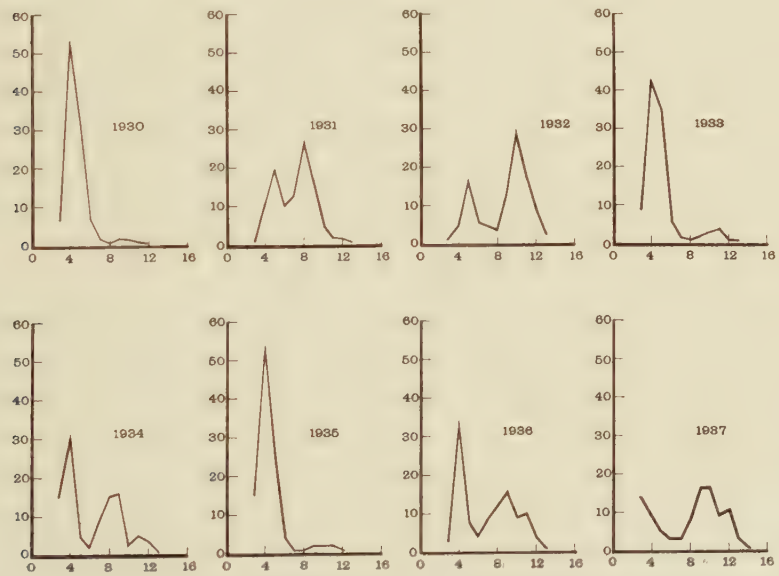

Fig. 6. Figure showing the size-frequency of the population of *Tellina fabula* at a depth of 2½ fathoms (station 7), Kames Bay, in the autumn of each year. *Ordinate*, % of total catch; *abscissa*, size in mm.

numbers of the older groups and tend to make the proportion of brood higher than it would be in an undisturbed population, a point to bear in mind when considering the size-frequency curves. No collection was made in September 1930 but one was made in February 1931 and it may be used instead as there is no growth over the winter and the population remains stationary.

Taking 6 mm. as an arbitrary figure to indicate the limit of the growth of the brood in the autumn of each year, then the proportion of the brood to the total catch in September of each year was as shown in the following table.

Year	% of spat	Year	% of spat
1926	92·9	1934	50·4
1930	94·5	1935	93·7
1931	39·6	1936	44·2
1932	26·0	1937	32·2
1933	90·1		

Making allowances for the two sources of error already mentioned, it would still seem that in the years 1926, 1930, 1933 and 1935 large broods of *T. fabula* occurred. The years 1926, 1930, 1933 and 1936 were the years of the large broods of *T. tenuis*, so that the two species coincide except for the last year. It has already been shown that there was a large drop in *St* from 1933 to 1934 and that might explain why there were no large broods in that year in spite of the fact that *St* remained positive. There is no such reason as to why there was no large brood of *T. tenuis* in 1935, when there was a slight rise in *St* and when one might have been expected. It is important to note that there was one for *T. fabula* in 1935. On the other hand, there was no large brood of *T. fabula* in 1936 although there was one of *T. tenuis*. Only further observations can solve the problem, but at this stage it would seem that, as already suggested, when the changes in *St* are sharp, upwards, large and reach a certain figure then large broods follow. When, as has been the case since 1932, *St* has remained fairly high without showing sharp fluctuations, large spats will come during that period but not every year nor, as in the case of the two species of *Tellina*, in the same year.

4. Summary

1. This paper deals with the possible correlation between the broods of *Tellina tenuis* and *T. fabula* in Kames Bay Millport, and temperature, sunshine and rainfall. The two species occur in the area of the littoral and sublittoral influences, respectively.

2. While some brood is found every year, the years 1926, 1930, 1933 and 1936 were marked by very large broods of *T. tenuis*.

3. There is apparently a close relation between the occurrence of these spats and the temperature in most years. The algebraic sum of the deviations of the monthly means from a standard set of means (*St*) for the period April to September of each year shows sharp rises in the years 1926, 1930 and 1933.

4. The quantity of brood seems to be proportional to the rise in *St*.

5. There seems to be practically no relation between sunshine and these years of large broods in *T. tenuis*.

6. There seems to be no relation between the rainfall and these years of large broods in *T. tenuis*.

7. The years of the large broods of *T. fabula* have been the same as those for *T. tenuis* (1926, 1930 and 1933) except in the period when *St* was high and fairly steady when it came the year before, 1935 instead of 1936.

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A SURVEY OF THE VERTEBRATE FAUNA OF THE ISLE OF MAY (FIRTH OF FORTH)

By H. N. SOUTHERN

(*With* 1 *Map*)

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A. NOTE ON THE HOUSE MOUSE (*MUS MUSCULUS*)

Twelve examples of *Mus musculus* L. were trapped on the Isle of May during July 1936. Ordinary break-back traps were used and these were set at night and visited in the early morning, and during the following day. The interval that must have occurred between trapping and collecting in many cases probably accounts for the small number of fleas (Siphonaptera) recorded. In one of the two cases where they were found the individual was still alive in the trap. Many mites (Acarina) were collected from some of the specimens. All these belonged to the species *Aleurobius farinae* Koch, and had evidently come from the storehouses that the mice frequented.

Trapping was first carried out in the outhouses and stores of the lighthouse buildings; but since only small numbers were obtained in this way, the walls of the various enclosed fields were tried, with a much higher yield. Towards the end of the visit, however, a period of wet weather intervened, and most were then caught again in the outhouses.

The Isle of May is five miles distant from the nearest coast (that of Fife to the north). The rest of the mammal fauna consists entirely of rabbits (*Oryctolagus cuniculus* L.). The lighthouse keepers are certain that there are no rats, and trapping along the rocks near the coast produced no shrews.

I wish very gratefully to acknowledge the help given me in identification by the following experts: Dr H. A. Baylis (parasitic worms); Mr F. J. Cox (Siphonaptera); and Mrs Margaret Hughes (Acarina).

Table of weights, measurements, parasitization

Specimen	Sex	Date (July)	Wt. (g.)	Body plus tail length (mm.)	Tail length (mm.)	Ectoparasites	Endoparasites	Remarks
1	♂	11	23·75	175	80	Many mites (see above)	None	Brought in dead, not examined till 12 hr. since death
2	♂	11	18·5	155	72	None	3 nematodes (*Trichuris muris* Schrank)	Examined very soon after death
3		12	26·0	159	75	Many mites	5 nematodes in caecum	Examined following morning. Four embryos weighing 3·5 g. deducted from weight
4	♀	17	18·5	145	66	Many mites	None	Examined following morning
5	♀	18	24·0	169	75	Many mites	4 nematodes in caecum	Examined following morning
6	♂	22	17·0	154	70	Many mites, 1 flea (*Nosopsyllus fasciatus* Bose)	2 nematodes in caecum	Examined about 12 hr. after death
7	♀	22	16·0	144	65	Many mites	None	Found as above
8	♂	22	24·0	156	75	Few mites	None	Examined following morning
9	♂	22	16·0	145	74	None	1 nematode in caecum	As above
10	♀	22	23·5	165	75	None	None	Examined shortly after death. Cestode cyst (? sp.) in liver
11	♂	23	18·5	155	75	1 mite	1 nematode in caecum	Examined following morning
12	♂	23	10·0	125	65	No mites, 3 fleas (*Nosopsyllus fasciatus*)	None	Caught alive, examined at once

B. CENSUS OF BREEDING BIRDS

1. Scope of the survey

The census was carried out under certain difficulties which made it impossible to achieve as great a completeness as is desirable. In the first place the work was done during the period, 2–26 July, when a number of the resident Passerines had finished breeding, and it was only possible to make a rough estimate of the pairs present by judging from the total of birds seen, including fledged young. Secondly, all observations were made by the author alone with the consequent difficulty of covering much ground at a time. Finally, it was not feasible to make more than an estimate of the cliff populations, though the methods adopted should have given a certain degree of accuracy.

The aim of the enquiry was not to make a complete biological survey, though a vegetational map was made with the help of another member of the party, and where such environmental factors are thought to have had an effect upon the distribution of the birds, they are mentioned. The two main objects in view were (*a*) to estimate the population of the resident Passerines to give a criterion for judging the influx of migrants of the same species, and (*b*) to estimate the total strength of the breeding birds of all kinds to afford a basis of comparison for previous and subsequent work of a similar nature.

2. Methods adopted

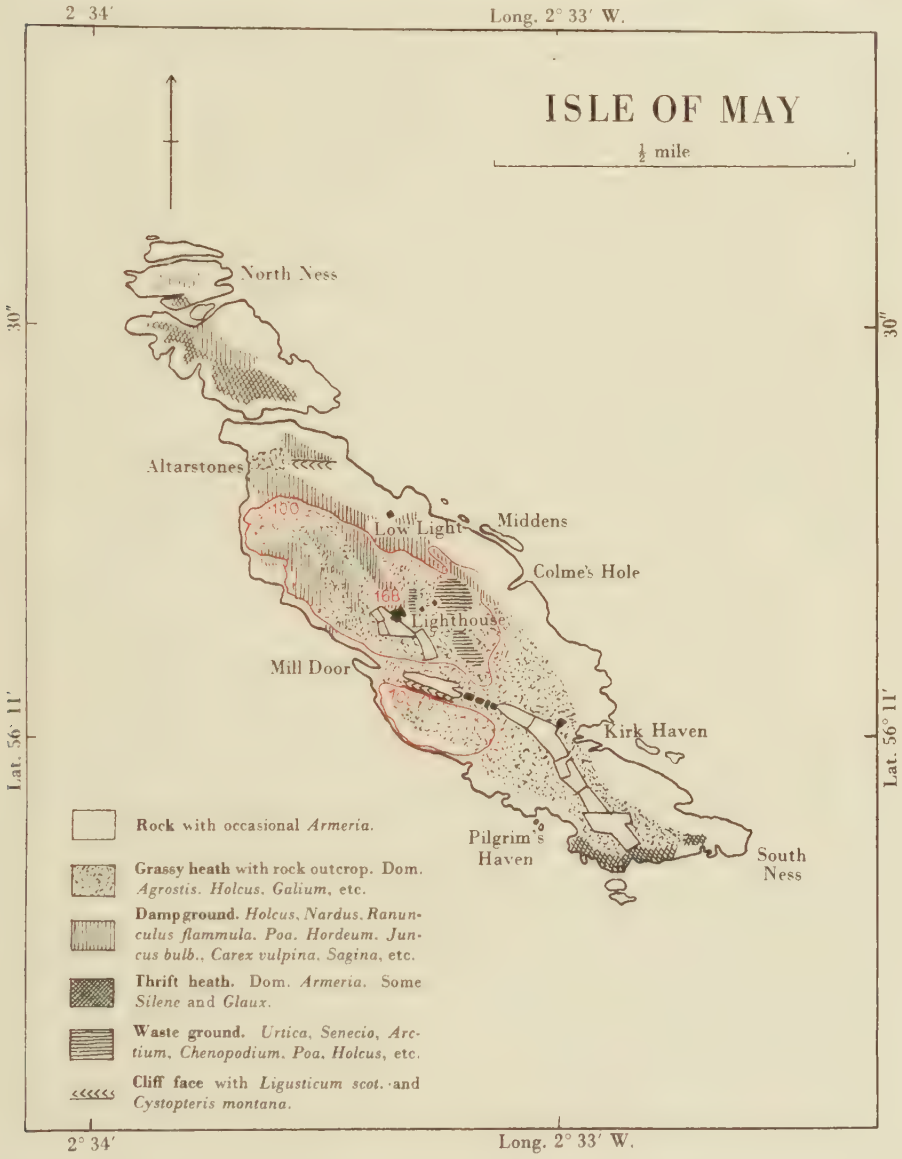
The aim in every case was to count the total population of the birds and not to rely upon sample areas, with the single exception of the ternery, where the calculation was straightforward owing to their even distribution. In the case of the rock pipits, practically all the adults were still holding territory in the earlier part of July, so that a circuit of the coast gave the required information. The blackbirds and song thrushes still remained more or less in their original territories with their fledged young during the first week, and the same applied to the pied wagtails and to the meadow pipits, but the starlings and house sparrows gave more difficulty. After about a fortnight the birds of the year of both species formed two self-contained flocks, so that a rough estimate of the pairs likely to produce so many young could be arrived at.

Worst of all were the wheatears and eiders: the former were in heavy moult and kept out of the way, while the eiders had practically all hatched their families, and the drakes had disappeared, with the exception of two birds in very black plumage. However, none of the young appeared to be very old, and it is possible that the count of families taken represents fairly accurately the number of pairs nesting, with the exception of unsuccessful ones. None of the families had combined at that time.

The oyster-catchers and lesser black-backed gulls presented little difficulty on account of the smallness of their numbers; while the herring gulls only required a little patience, since they were concentrated at two focal points,

with a sprinkling round the rest of the coast that could easily be counted by a circuit.

In the case of the cliff birds the job was rather laborious but by no means impossible. The actual methods varied with the species: with the fulmars and



shags it was a case of marking down each nest from the cliff tops and then checking them from the sea; adding such as had been missed on account of overhangs, clefts, etc. The kittiwakes were most easily estimated by counting

the nests from the seaward side; while in the case of the guillemots and razorbills an attempt was made to count the actual parent birds.

It was impossible to distinguish the two species from a rocking boat, so a count was first taken of the total of both kinds actually on the cliffs. Later a count was taken at the same time of day and under the same weather conditions from the cliff tops of the birds on the water, and the proportion of razorbills to guillemots carefully noted. The same proportion was applied to the previous count on the cliffs and the totals added together. Puffins presented obvious difficulties on account of their hole nesting habits; but a similar count was taken including both birds on the water and on the cliffs. A further addition of about 40 % of this total for incubating birds seems not unreasonable.

The procedure at the ternery was almost rule of thumb. About eight sample squares of ground in all parts of the ternery were marked out, measuring 20 by 20 yd. (i.e. 400 sq. yd.) and the number of nests in each carefully counted. It was found that these samples fell fairly distinctly into three classes, of which one averaged 80 nests, the second 45 nests, and the third 30 nests. There were only two foci with the very dense population, while the majority of the ground fell into the second class, the third composing the outlying areas. Thus it was possible by pacing out the whole extent of the ternery, and making the necessary allowances for the small areas of greatest and least density to arrive at an accurate idea of the total number of nests. From this datum it was easy to separate off the Sandwich terns on account of their small numbers. Towards the end of the month the author was assisted by Mr Frank Elder to count the number of arctic terns, thus completing the whole survey.

3. General topography and the main communities

The Isle of May is about $1\frac{1}{2}$ miles long and $\frac{1}{4}$ mile broad and its long axis is orientated slightly west of north and east of south. The rock is basalt, forming sheer cliffs about 100 ft. high on the west side, and either low cliffs or irregular rocky terraces and slopes on the east side. The northern part of the island is cut off from the rest at high tide. It consists of low, uneven ground and is occupied chiefly by the terns. The main part of the island is grooved in a north-west to south-east direction by a valley that provides some shelter.

With the exception of the North Ness, which has sparse vegetation with *Rumex* and *Silene*, the major part of the island consists of a rough turfy surface characterized chiefly by *Holcus*, *Agrostis*, *Nardus*, *Galium*, *Cerastium*, *Potentilla*, etc., with frequent outcrops of rock. Practically the whole circumference is covered with dominant *Armeria*, which extends even along the west side of the North Ness.

The presence of man has two aspects: the occupation of the valley with the construction of a fresh-water loch at the north-west end, and the walling in of certain areas to form enclosures, of which the trapping garden is one. Here an

abundance of weeds has settled. The other effect of man's presence is the large cap of cinders and coal dust deposited on top of the island near the old beacon, which has been captured by *Urtica*, *Carduus*, *Arctium*, *Chenopodium*, *Ranunculus*, *Poa*, etc. From this centre other patches have been colonized by these plants.

Of mammals living on the island there are only two and by far the more important is the rabbit (*Oryctolagus cuniculus*), which swarms all over it. By its agency the turf is kept close cropped, and the burrows may offer retreats to some puffins, wheatears, etc. No doubt rabbits also provide a certain amount of food for the gulls. The resident house mouse (*Mus musculus*) is of the large insular variety found on many islands round the British Isles, and is confined in its distribution to the valley. Trapping along the rocks failed to produce any shrews and apparently there are no rats on the island.

The insect population is fairly varied and was studied by another member of the party, Mr H. G. Callan, who will publish his results in due course.

The birds may be divided roughly into the following communities: (*a*) the small Passerines that occupy the greater part of the island and get their food from it; (*b*) birds that nest and feed along the shore, represented only by the oyster-catcher; (*c*) birds that use the island only for nesting and occupy the cliffs or the other margins and the North Ness; and (*d*) half-way birds that nest along the margins or a little way above them and get some of their food from the island. It is under these headings that the figures will now be considered.

4. Census results

(*a*) *Passerines*

Rock pipit (*Anthus spinoletta petrosus*). 24 pairs. This is perhaps the most characteristic bird of the island. Its distribution is fairly even all round the margin, with some concentration along the East Rocks. The cove known as Colme's Hole was such a satisfactory habitat that two pairs were breeding in it, the nests being not more than a dozen yards apart. One nest had newly hatched young on 12 July, though they were subsequently deserted upon the establishment of a roost of first-brood young in the cleft concerned.[1] The two other nests found both had young in much later stages of development. All had a high proportion of unfertile eggs, which may indicate exhaustion of the reproductive organs in such late broods. The first-brood young ranged all over the top of the island as well as the margins and frequently fed in the waste patches of ground near the Observatory. Birds were also found roosting in company in patches of nettles, and in rock clefts, as noted above.

Meadow pipit (*Anthus pratensis*). 2 pairs. This species showed a constant difference in habitat selection from the foregoing. During the first week they were seen ranging over the turfy ground on top of the island, and after that they seemed to feed for the greater part in and around the sheltered fields in the valley.

Wheatear (*Oenanthe oe. oenanthe*). 3 pairs. Very difficult to assess correctly. However since three of the birds seen were probably cocks, though disguised in heavy moult, and twelve birds in all were seen, the figure seems not unreasonable. These again were distributed much in the same way as the meadow pipits except that they preferred the ground with more rock outcrop.

[1] For further notes on this subject, see **Southern, H. N.** (1937). Brit. Birds, 29: 2.

The three preceding species might be called the truly indigenous birds of the Isle of May, since they inhabit the ground that is most typical of it. The following ones are all in some degree invaders, probably having arrived in the trail of man.

Starling (*Sturnus v. vulgaris*). 6 pairs. There may possibly have been a previous indigenous stock of these birds on the island nesting in rabbit holes, crannies in the cliff, etc.; but this seems unlikely in view of the history of the starling in the surrounding region of Scotland (**1**). It has more probably spread to the island contemporaneously with its increase on the mainland. Starlings were principally to be seen round the premises of the lighthouse keepers and various derelict buildings with their fledged broods, though they covered the whole island in their foraging sporadically, even working the North Ness. The family parties were observed later to be joined up into one flock.

House sparrow (*Passer d. domesticus*). 6 pairs. Naturally this species is even more confined than the starling to the buildings, and most of them inhabit the valley, though one female was seen at the Low Light. The young birds had formed a flock of about 20 by the third week and were to be seen mostly in the fields and gardens. Many were trapped and found to be infested by a bird fly (*Ornithomyia fringillina* Curtis) to the extent of half a dozen to each individual. As many as ten were produced by one unfortunate.

British song thrush (*Turdus e. ericetorum*). 2 pairs. One pair of these birds lived in the valley; but the other occupied the part of Holyman's Road near the Low Light (where the slight dip gives some shelter), being thus independent of man.

Blackbird (*Turdus m. merula*). 3 pairs. These were confined to the valley and to the lighthouse gardens for breeding, though odd birds hunted somewhat further afield. A favourite place for one male was in the waste patch round the Observatory.

Pied wagtail (*Motacilla alba yarrellii*). 2 pairs. This species is perhaps not quite so dependent upon man as the four previously mentioned, but one pair with fledged young was continually seen round the fresh-water loch, and the lighthouse grounds nearby, while the other pair frequented the lower fields near the Priory. These again fed over a wider area sporadically, being encountered round the Observatory and on the ground between the East Rocks and the valley.

This completes the list of the Passerines. Fortunately no complications due to migrant birds were introduced, so the total given (48 pairs) is a pretty fair estimate of the real population. It is to be noticed that the rock pipit is the bird really characteristic of this community, and all the others are living rather near the danger margin as regards numbers.

(*b*) *Shore birds*

Oyster-catcher (*Haematopus ostralegus occidentalis*). 7 pairs. The formation of the shoreline does not encourage a large population of shore birds, and it is interesting to find that only this species has managed to establish itself. The individual pairs are scattered fairly well round the island, and for the most part keep to the low broken rocks such as those at the North and South Ness. An exception however is a pair that was constantly seen on top of the cliffs just behind the fresh-water loch. Two nests were found, one of which still contained eggs on 25 July.

(*c*) *Cliff birds and the ternery*

(The eider is included in this category, as being a bird that feeds at sea, and merely uses the land to nest.)

Kittiwake (*Rissa t. tridactyla*). 2950 pairs. The most abundant of the cliff community, preferring the higher and more perpendicular cliffs from 50 to 100 ft. high. On such a formation as this, where the basalt tends to split and leave platforms rather than continuous ledges the nests are often disposed in an inverted V-shape, which would give the maximum crowding without any of the nests being over one another. It can easily be seen by observing the way in which the cliffs are "whitewashed", that the kittiwake prefers to nest under an overhang or under a small jutting "umbrella" of rock. In this way their plumage is kept clean in sharp contradistinction to that of the guillemots. Wherever there was the slightest chance it was noticeable that these birds strung themselves in typical single lines.

A count was taken one morning to get an idea of the rate of chick survival. The figures must be taken as the maximum, for some of the nests had eggs still; in most cases however the young were fairly large and had a reasonable chance of being fledged. No. of nests with 2 *young* (*or eggs*), 50; 1 *young* (*or egg*), 28; *no young* (*or eggs*), 10.

Northern guillemot (*Uria a. aalge*). 2080 pairs. The formation of the rocks did not allow these birds to crowd together in their usual hordes, and they were for the most part distributed in groups of a score or so on each platform. In this way there was not so much communism in the care of eggs and young as at some of the larger colonies. In some places, owing to the stepped formation of the basalt, birds were nesting much lower down the cliffs than is usual, and in flying off they usually bounced off the water once or twice before they could get under way.

The cliffs were carefully examined under all possible light conditions, and it seemed certain that there was a small admixture of the southern form, as would be natural so close to the edge of its range.

A count was taken on all the cliff faces as far as the Mill Door from the direction of the Angel to determine the proportion of the "ringed" variety from as large a figure as possible. In all 1468 were counted, of which 72 were ringed, giving a proportion of just over 5%. Only in one instance were two ringed birds seen to be mated together.

Razorbill (*Alca torda britannica*). 500 pairs. These birds occupied much the same area as the guillemots except that they spread out further on to the lower and more broken-up cliffs.

Puffin (*Fratercula arctica grabae*). ? 50 pairs. A superficial count gives the impression that puffins are very few on the island, but there is little reason to doubt the figure given, as explained above. They inhabited the topmost parts of the cliffs, and the majority of them occurred on the cliffs between the Mill Door and the West Landing.

Shag (*Phalacrocorax a. aristotelis*). 10 pairs. These birds hide themselves away so efficiently in cracks and caves that they are not easy to count. In addition the immature birds that hang about have to be carefully distinguished from the breeding adults. One crevice was found which contained a small colony of three nests, and the rest were distributed along the lower portion of the more precipitous cliffs.

Fulmar (*Fulmarus g. glacialis*). 4 pairs. These were split up into two groups of two, one nesting upon ordinary broken cliff and the other upon a face sufficiently out of the perpendicular for rough grass and turf to cover it. Incubation was still going on.

Eider (*Somateria m. mollissima*). 32 pairs. As explained, this figure is based upon the actual number of families seen. In addition 37 other ducks were seen either singly or in groups, but with no ducklings. Most of these were distributed round the North Ness, the South Ness and the east side. One bird was still sitting in among the gulls on the rock known as the Maiden's Hair. Most of the old nests appeared to be just above the rocks in the belt of thrift. Families averaged about three ducklings.

Common tern (*Sterna h. hirundo*). 3400 pairs. Practically all were nesting on the North Ness with the exception of two pairs on the East Rocks not far from Kirk Haven. The body of them occupied the peaty ground in between the rock pools among the *Rumex* vegetation and the somewhat higher *Armeria*-covered ground on the west side of the North Ness. The

two foci of densest population were, curiously, some way apart from the others, one being on the rocks just above the Tarpot, the other one the single patch of shingle near Norman Rock. Each of these contained about 200 nests.

Arctic tern (*Sterna macrura*). 800 pairs. These kept in a compact body on the bare rocky ground to the east and south of the common terns.

Sandwich tern (*Sterna s. sandvickensis*). 4 pairs. These nested in among the common terns, and it was observed that although they kept together in a group, they were molested by their neighbours every time they attempted to approach their nests. One by one the eggs were found broken and sucked, and finally the birds gave up the attempt to breed.

It is as well to mention in view of the curious desertion of the colony that took place later that all the terns were still there on 26 July, most of them having chicks about a week old.

(*d*) *Partly predatory species*

Herring gull (*Larus a. argentatus*). 455 pairs. The two main colonies of these were on outlying rocks, one being the Middens on the east side and the other the Maiden's Hair rock not far from the foghorn. In addition they nested on the South Ness and all along the top of the rocks from there to the beginning of the higher cliffs, and then again in rather scattered pairs on the west side of the North Ness. In every instance they prefer to nest on the actual rocky edge of the cliff or a little way down it. Most of the young birds caught for ringing purposes disgorged small fish, but no doubt the adults feed upon rabbits and eggs a good deal.

British lesser black-backed gull (*Larus fuscus affinis*). 7 pairs. Only one of these pairs nested on the Middens, the others preferring the turfy slopes near the foghorn, just above the line of the cliffs where the herring gulls lived. Even when in such small numbers their habitat selection holds good.

5. Non-breeding birds

As far as could be ascertained there were very few of these, except in the case of the gulls. There was usually a flock of anything up to 200 immature and mature birds to be seen either on the South Ness or on the Norman Rock at the North Ness. The majority was coming into adult plumage and had only a little brown in the wings and a band across the tail. Most of these were herring gulls, though perhaps half a dozen were lesser black-backs. On 20 July, 11 mature and 9 immature greater black-backed gulls (*Larus marinus*) were seen with this flock on the Norman Rock. It is difficult to classify them exactly, since the presence of the mature birds may point to the beginning of a migratory movement.

There were always some shags around the coast, and a congregation of 20 together with a couple of cormorants (*Phalacrocorax c. carbo*) was seen one day on Norman Rock. Most showed the whitish underparts of the immature bird. The 37 eider ducks have already been mentioned. Whether their non-breeding was due to the destruction of nests is not sure. The only other non-breeders were a couple of Sandwich terns, whose nest had probably been destroyed before the party's arrival.

6. Comparison with previous work

The strength of the breeding population on the Isle of May was roughly summarized by Rintoul & Baxter in 1925 (**2**) and there are some interesting comparisons. In 1936 there was no sign of the carrion crow which they record,

nor of the moorhen noted by Elder (**3**), though the former bred until 1929 (L. J. Rintoul in private communication). Other variations are in the starling, recorded as 25 pairs in 1924, and "decreasing" in 1925; in the pied wagtail described as "stationary"[1] (presumably at the figure of 3 or 4 pairs mentioned (**4**)). The eider is difficult to assess, but it appears as if there had been probably some falling off from the figure of 83 pairs in 1925. Meadow and rock pipits are said to have been "decreasing", the only known figures being 3 pairs of the former in 1924 and 31 pairs of the latter in the same year (L. J. Rintoul, private communication).

On the other hand many species have increased: the house sparrow, which had settled at about 2 pairs in 1924, has now risen to 6; while the song thrush, which was then lost, recommenced breeding in 1931 (H. F. D. Elder in private communication) and is now represented by 2 pairs. The blackbird has similarly regained ground, for only one female was seen in 1925 and it did not recommence to breed until 1930 (L. J. Rintoul). The wheatear was confined to 2 pairs in 1925, and in spite of the approximate nature of the estimate given here, shows a clear increase, while the same applies to the shag and the fulmar, both quoted at about 2 pairs.

The increase of the herring gull is quite remarkable; from 58 pairs in 1924, the figure now stands at 455. Unfortunately nothing is known about the intervening years, so that the curve of increase cannot be plotted with accuracy. The lesser black-backed gull is a comparative newcomer, 2 pairs being recorded by Rintoul & Baxter in 1933 (**5**), and it seems probable that their increase will continue.

The only other figure of interest is that for the oyster-catcher, which is said to have risen to 7 pairs by 1921, and to have continued at that until 1925. There may have been slight fluctuations in the intervening years, but evidently the figure is a very steady one, for my census gives exactly the same number of pairs.

7. Acknowledgements

In conclusion the author wishes to express his gratitude to the Commissioners for Northern Lights for permission to stay on the island and for other favours; to the Chief Lighthouse Keeper and other members of the staff for their great help and agreeable company; and to the Midlothian Ornithological Club for the interest and co-operation they displayed, as well as for the use of the Observatory.

C. SUMMARY

A. Twelve house mice (*Mus musculus*) were trapped in buildings and in field walls. Their measurements and parasites are recorded. They belonged to a comparatively large race.

[1] Four pairs bred in 1924 (L. J. Rintoul).

B. A breeding bird census of the Isle of May was carried out in July 1936. The methods are described. The chief care was to produce definition in the figures, with the greatest possible amount of accuracy, to form a concrete basis for comparison with (*a*) the fluctuations due to migrant Passerines, and (*b*) future estimates of the strength of any or all of the breeding birds. The environment is defined in its main features, and the birds are treated not in their systematic order, but in their natural ecological groups. Finally, a brief comparative account of the numbers found by previous workers is given.

REFERENCES

1. **Rintoul, L. J. & Baxter, E. V. (1935).** "Vertebrate fauna of Forth." Edinburgh p. 63.
2. **Rintoul, L. J. & Baxter, E. V. (1925).** Scot. Nat.: 175.
3. **Elder, H. F. D. (1935).** Scot. Nat.: 47.
4. **Rintoul, L. J. & Baxter, E. V. (1918).** Ibis: 264.
5. **Rintoul, L. J. & Baxter, E. V. (1933).** Scot. Nat.: 182.

ERRATA

"A contribution to the ecology of a grassland community on Guadalcanal Island, British Solomon Islands Protectorate.' *J. Animal Ecology*, 1937, Vol. 6, pp. 291–7.

Page 295, line 4. Omit the word flycatcher.

Page 295, line 6. Add nests in *Themeda*.

Page 296. After Hymenoptera delete (18) and substitute (21).

Add, after *Sphex cognatus* Sm. Prey of spider A 2.

Substitute wasp for bee for two species of *Polistes*.

Add: *Crocisa gemminata* Ckll. On leaf tip of *Imperata*.
Polistes variabilis F.
Eumenes latreillei Sauss., var. *petiolaris* Schulz.

Line 7 of text. For temperature read temperate.

REVIEWS

THE JOURNAL OF ECOLOGY

(Vol. 26, No. 1, February 1938)

This number of 254 pages contains eleven original papers and four reviews, together with the customary annual report of the activities of the British Ecological Society, together with list of members and statement of accounts.

The original papers include three dealing with different forms of survey work. C. J. W. Pitt-Schenkel describes the important plant communities of a warm temperate rain forest (dominated by camphor-*Ocotea*) at Magamba, West Usambara in the Tanganyika Territory. W. Davies describes the vegetation of grass verges and other excessively trodden habitats in Britain, and N. Mary Martin the epiphytic moss flora of trees in Argyll and the effects on this flora of exposure and of the nature of the tree bark.

A. S. Watt contributes part 3 of his studies in the ecology of Breckland, which deals with the development of *Festuco-Agrostidetum* on infertile sand and with the role of moss-lichen communities in this succession.

Three papers deal with marine or maritime plants and their habitats. Dorothy C. Gibb describes the composition of the algal communities of Castletown Bay, Isle of Man and their relation to tidal range and season, while M. B. Hyde presents data on the effects of temperature and light intensity on the rate of apparent photosynthesis in *Fucus serratus*. V. J. Chapman ("Studies in salt-marsh ecology, I–III") discusses the habitat factors operating on the Norfolk salt marshes, and particularly the effects of tidal range, soil drainage and aeration.

Two papers by W. H. Pearsall on the soil complex in relation to vegetation deal respectively with oxidation-reduction potentials in soils and with characteristic woodland soils. J. F. Hope Simpson contributes a comparative analysis of the flora and soil conditions of a small calcareous area on the Lower Greensand, giving lists of calcifuge and calcicole species. Oliver West discusses the method of determining changes in grassland composition and the statistical treatment of results.

W. H. PEARSALL.

THE ECOLOGICAL METHOD

J. W. Bews (1937). *Life as a Whole.* 347 pp. Longmans, Green and Co. Ltd., 39 Paternoster Row, London, E.C. 4. Price 15*s*.

Life as a Whole supplements Dr Bews's previously published *Human Ecology* and purports to demonstrate, in its discussion of the autecology and synecology of mankind, the ecological method. As yet there has been no serious statement of the ecological position, most writers having left it to be inferred from their accounts of ecological activities. Much, however, has been said and written about the "ecological point of view" or ecology "as a point of view", but there has been little indication of where an enquirer should stand in order to inspect the panorama which, presumably, is offered to him. The ecological *Weltanschauung* is, we may suppose, fairly clear to those initiated into it, since, as Dr Bews remarked in his earlier work, it produces so much enthusiasm. Ecologists must now stand indebted to Dr Bews for the first expanded and, on the whole, clear statement of the meaning of their subject and the source of their enthusiasm. That they may not agree with his interpretation and that he has ignored alternative versions, is beside the point. He has, at least, given a basis for argument.

Ecology, for Dr Bews, is the practical application to nature of General Smuts's philosophy of Holism. The principles of this philosophy are now of general familiarity and there is little need to dwell on them here. "Holism...recognises the tendency of reality everywhere to create wholes, each whole being an integrated structure, which is something different from the sum of its parts." The process of the "creation of wholes" is known to all ecologists. It is expressive of the tendency of systems towards more complete stabilization; a process recognized in the progress of the sere to the climax or of the subsiding into steady rhythm of a predator-prey fluctuation. Ecology recognizes these "wholes" and its appointed task is to analyse them and having done so, to make syntheses in which integrations, formerly hidden, become apparent. Now, if this is the meaning of ecology, various questions arise of which one may be asked. In what way does ecology differ from other biological sciences?

Some difference is clearly implied. It is stated that this holistic (and hence ecological) method provides an alternative to the "merely mechanistic and analytical approach to scientific problems". Yet it is difficult to see the difference between the ecologist who "works by collecting facts, classifying them and arranging them, and fitting them together into constructive syntheses", and another scientist who does precisely the same thing even if he does call his constructive synthesis an hypothesis. In fact, so far as it implies the use of procedures differing from what is usually called the scientific method we must infer that the "ecological viewpoint" is meaningless. Unless, indeed, geneticists and cytologists, embryologists and physiologists, let alone astronomers and psychologists, are, if good scientists, also unwittingly ecologists. And, although this may seem nonsensical, Dr Bews cannot think so—and he is by no means alone in his belief in the magic powers of the ecological arcanum – for he states that the adoption of "the ecological standpoint" is "the beginning of wisdom". This exaltation of their subject may be familiar to many people, it being a feature often present in the writings of American ecologists, but evidently there is confusion of thought behind it.

Ecology should not be confused with the conclusions it draws nor with the organicist or holistic philosophies it uses to form a unifying background to the natural complexities it reveals. It may well be that ecology will provide evidence for the truth of such philosophies, but it should not be identified with them. It should be remembered that other branches of biology also use these methods of thought, and it will be found that their implications have been very thoroughly explored by non-ecological biologists, for example in the writings of Woodger, Needham, von Bertalanffy; and ecologists might well profit by occasional returns to the laboratory science they often affect to despise. The views of Dr Bews and others who exalt the ecological viewpoint as the key to knowledge will be vindicated when other older established sciences acknowledge themselves but offshoots of the super-science of ecology.

Little space is left to remark on the data Dr Bews uses in his discussion of human ecology. The first half of the book is devoted to a discussion of the morphological, physiological and psychological changes occurring during the life of a typical specimen of mankind. The second forms an account, necessarily rather superficial, of human activities. Here, especially, Dr Bews's notions of the scope of ecology have led him away from what might be supposed its legitimate province. We learn that Cézanne had the makings of a good ecologist; though an artist who certainly has some claim to that title, H. G. Wells, is only mentioned as a novelist. There are lengthy catalogues of human notabilities from Thales to A. N. Whitehead, from Palestrina to Schönberg, but no mention of human population changes and the work of the demographers.

It is probably true that ecology tends more than most sciences to encourage a broader outlook, but to pretend that it is the fount of all wisdom is vanity.

JOHN FORD.

THE SURVIVAL OF MAMMALS

(1) **Joseph Grinnell, Joseph S. Dixon & Jean M. Linsdale (1937).** *Fur-bearing mammals of California. Their natural history, systematic status, and relations to man.* 2 vols., 777 pp. and 13 coloured plates. University of California Press, Berkeley, California. Price $15.

(2) **Lee R. Dice & Philip M. Blossom (1937).** *Studies of mammalian ecology in southwestern North America, with special attention to the colors of desert mammals.* 129 pp., 7 text-figures, 8 plates. Carnegie Institute of Washington, Publ. No. 485.

(1) It is elementary to state that wild animals can be successfully conserved or controlled only through long term programmes based on sound knowledge. Despite this, the administrative system in most of the United States and Canadian provinces makes it possible for the personnel of the department in charge of wild life to change with the electoral complexion. For this reason the State or Provincial universities and museums are of immense importance as permanent centres for the accumulation of data and the maintenance of organized research. The two volumes under review are an excellent example of the manner in which this function should be fulfilled. Here is set out that broad basis of fact which should be available in every state or province where wild animals are important assets or liabilities.

As an example of wise legislation the authors cite the policy of the California Fish and Game Commission in 1911–15 when beaver could be taken only under special licence. This was granted (without too much "red tape") for areas where their burrowing and dam-building habits had made them a nuisance or danger. In 1920 beaver ranked tenth in value of the fur bearers of California; but through the present lack of State protection they are in serious danger of extermination. In the period 1920–24 the striped skunk headed the list in aggregate value to trappers. Because skunks are widely distributed and easy to trap they are a source of income to many people to whom the money is the difference between a livelihood and penury. Yet general appreciation of the value to the state of such an animal as the skunk may easily be prevented by outcries against its often imaginary depredations. The true picture of an animal's worth can only be gained from an impartial survey such as these authors present. Those *individuals* should be destroyed that cause economic loss, but for aesthetic, recreational, humane, ecological and economic reasons, wholesale slaughter should not be tolerated.

The treatment of the material is first a description in small type of the systematics of each race or species. This is followed by a variety of natural history observations, distribution, population trends and densities, estimates of economic position, and recommendations. The editing and weighing of the information gathered direct from trappers, sportsmen and others are very carefully done and show the continual importance of this phase of ecological research. The fine coloured illustrations by Major Allan Brooks are another powerful attraction of these volumes. The chapter on "population trends of fur bearers" is a particularly able analysis of the factors responsible for the state's declining fur resources. It is to be hoped that the direction of this trend will be altered through wise use of the information so well presented here.

(2) One of the frequent differences between "natural history" and modern ecology is that in the latter certain natural phenomena are expressed in terms of measurable units. This possibility is usually dependent on advances in technique. In the past few years methods have been developed by Dice and his co-workers of expressing the colours of mammal skins through the use of a tint photometer. Readings are taken principally of the reflected red, green and blue-violet, low readings indicating a dark colour. The technique is now extended to the measurement of the colour of surface soils.

South-western Arizona especially is characterized by well-pronounced life belts, more or less closely correlated with altitude: montane forest, encinal (i.e. characterized by oak and

sycamore associations), arid grassland, desert. The desert soils are pale, those of the montane belt are dark, and soils from the other belts have intermediate tint photometer readings. These differences are due to differences in amount of humus which is determined through the influence of atmospheric humidity on vegetation. 473 individuals of some 20 species were examined and a close correlation was found between pelage colour and life belt.

Much of the country consists of desert, out of which isolated mountains rise sharply. Some of these are composed predominantly of rocks of one colour. The pocket mouse *Perognathus intermedius* is largely confined to these rock hill habitats, and between the colour of the dorsal pelage of its several subspecies and that of the rocks there is a correlation coefficient as high as 0·8. Through the work of F. B. Sumner, the deer mouse *Peromyscus* has become a well-known example of the many species that exhibit geographic colour variations, light- and dark-coloured races often appearing on soils respectively of light and dark colour. The facts of this matching of soil by pelage cannot be explained by the operation of an internal factor alone or by differences in climate or vegetation. Two isolated mountains with different coloured rocks but with apparently identical climate and vegetation may support one a pale-, the other a dark-coloured race of the same species. Natural selection acting through some agency such as predators seems the most logical explanation for the differentiation of these local races. Isolation has no doubt been of importance; but where two races have contiguous distribution, inter-breeding does not result in general obliteration of the sub-specific differences. This seems to indicate the continued operation of the process which has differentiated the sub-species; but there is no reason to believe that the same process will eventually produce distinct species.

The first 73 pages of this paper contain the solid data resulting from the field surveys: description and classification of the biogeography and of the various species and associations. This section naturally requires careful study which might have been aided by incorporation of the plates in the text instead of at the end. The main thesis is well developed and easy to follow, since it is based on sound data adequately presented.

DENNIS CHITTY.

BIRD POPULATIONS

(1) **Margaret Morse Nice (1937).** *Studies in the life history of the song sparrow*, Vol. 1. Trans. Linn. Soc. New York, 4 : 1–247. The Linnaean Society of New York, c/o American Museum of Natural History, 77th St. and Central Park West, New York City. Price $1·50.

(2) **Aretas A. Saunders (1936).** *Ecology of the birds of Quaker Run Valley, Allegany State Park, New York.* New York State Museum Handbook No. 16 (New York State Museum Albany, N.Y.), 68 illustrations, including map. Price 50 cents.

(1) The modern technique of trapping and colour-ringing makes it possible to keep track of individual birds in the field. Anyone who reads this paper will be struck by the number of problems to which this method offers a new approach. The observations recorded are the result of eight years' intensive study of the song sparrow (*Melospiza melodia*) on a 30-acre strip of land near Columbus, Ohio. This land, which at first was waste, was later brought under cultivation. The work of the first year was confined to an intensive study of two pairs, and provided a valuable basis for the more extended observations which at one time covered 75 ringed males. The resulting survey is extremely comprehensive, covering migration, ecological relationships, territory, nesting parasitism by cowbirds, survival rates, age, and population fluctuations. A study of behaviour in more detail is reserved for a second volume.

The points of most general interest arise in connexion with migration and population. There were four categories of song sparrow in the area—resident, summer resident, winter

resident, and passage migrant, and it is to be noted that in a population showing "individual migration" of this type, permanent residents can only be distinguished by the ringing technique. The majority of birds under observation were consistent in migratory behaviour, but of a total of 55 males and 42 females six males and one female changed status, all but one of them becoming migrants after a period of residence. The genealogy of several families was worked out with reference to migration, but the results, while showing that the original idea of a sex-linked control is untenable, are not extensive enough to allow of further genetical analysis. It may be noted that the fact that birds can change their migratory status, does not, as the author suggests, exclude the possibility of an underlying genetical control; the proportion of changes is low.

The spring migrants tended to arrive in two distinct waves, and a close correlation was obtained between the time of arrival of the first wave and the air temperature. This is somewhat at variance with the views of many other authorities, who believe that temperature, particularly at the point of arrival, is of little importance. The suggestion is made that the early wave consists of birds strongly influenced by actual weather, while the main wave birds are largely controlled by "instinct" (more probably by increase of light). The temperature threshold for the arrival of the main wave is considerably lower than that for early birds, which suggests that temperature is not the fundamental factor but may exert a modifying effect on the general behaviour pattern.

The questions of age, mortality, and survival rate, are dealt with in some detail. During the third winter the land was brought under cultivation, and much of the undergrowth cleared, with the result that the population decreased sharply, mortality of adults during the breeding season being particularly high. This is believed to have been due to the increased effect of predators in a more exposed habitat, though evidence on this point is scanty. The general course of events is in accordance with the view that instability of the environment is an important cause of population fluctuation.

This is a stimulating paper with a bearing on several controversial questions. It provides a striking example of the value of continued study of individual birds, and it is to be hoped that other workers will be encouraged by it to undertake similar studies of common species. In conclusion mention must be made of the excellent summaries given at the end of each section.

(2) This paper is an enquiry into the numbers and distribution by habitat of the breeding bird population on an area of 17000 acres, combined with a more intensive study of one species, the ruby-throated humming-bird (*Archilochus colubris*). The areas and limits of the different habitat types were determined by sketch-mapping and traverses, checked where possible by rough triangulation. Sample areas were then laid out in each type of habitat, and the birds of each species within the area counted. Subsequently it was found possible to replace this rather laborious method by a series of travelling censuses, all distances being estimated by pacing, and all birds within fifty double paces on either side of the line being counted.

Counting, wherever possible, was based on singing males, and was carried out early in the morning during the first fortnight of July. Presumably all the actual counting was done in the same year, though this is not made clear. It is to be regretted that no information is given as to the percentage of the total areas actually sampled, as this would be of interest to those engaged in similar work.

A concise description of the plant ecology of each habitat is given. Only 10% of the whole area can be classed as open, and this includes meadows, field pastures, orchards, stream banks and buildings. The distribution of birds in these areas calls for little comment, the numbers and density of species increasing with the increase of trees and shrubs, and reaching a maximum of 15 species and 2·96 pairs to the acre in orchards. In the woodland areas two main forest types, oak-hickory and maple-beech, are distinguished, the latter predominating. Periodic felling and clearing in the maple-beech forest has produced areas of different ages, and hence it was possible to obtain some idea of the succession of bird species as re-afforestation progressed. The young "sprout-forest" is populated mainly by typical pasture-land species, which disappear when the forest canopy closes, being replaced gradually by wood-

land forms. The appearance of the latter can be correlated with such features as the development of humus and undergrowth and the accumulation of dead trees. The total number of breeding birds increases in proportion to the height of the trees.

The observations on the humming-bird include nest sites, nest materials, food competitors, pollination, and numbers. It was found that the basic food was the nectar of the bee-balm (*Monarda didyma*) which may grow either scattered or in clumps. The position of the clumps determined the site of nesting territories. The method of counting was thus to record the total number of clumps and then estimate the population from careful observations in a small area. The patches of bee-balm fluctuate from year to year, producing a corresponding shifting of nests. The males do not usually remain through the nesting season, but when present they occupy territories of their own, as do the nesting females. An instance is recorded of a male and a barren female fighting continually over a single territory.

Although much of the subject matter will appeal only to those who are familiar with American birds, the observations on succession are of some interest. Since they were confined to one year, the picture presented is that of a population at a given moment, and the bulk of the paper is necessarily purely descriptive.

C. H. HARTLEY.

THE NICHE OF THE LITTLE OWL

Alice Hibbert-Ware (1938). *Report on the Little Owl Food Enquiry, organized by the British Trust for Ornithology.* 74 pp. Illustrated by photos. H. F. and G. Witherby, London. Price 3*s.* 6*d.*

This publication is the result of a specific enquiry conducted for a specific purpose, so it is not for the ecologist to complain if figures that he would very much like to have seen are missing. The object of determining the precise qualitative nature of the food of the little owl (*Athene noctua vidalii*), and more generally its quantitative composition, has been most successfully carried out. The wild allegations that have been made about the depredations of this species have been answered in the most effective way.

The section on distribution and numbers is interesting: after its initial introduction into this country between 1894 and 1900 the little owl spread rapidly and became very abundant in places. Now reports indicate that in most districts the population is either stationary or falling off, while there are only two indications of actual increase (in the West Riding and Carmarthen). Censuses give from 2 to 4 pairs in a half-mile radius of favourable country.

The food analysis was made from three sources: 2460 pellets, 76 nest contents and 28 gizzard contents. The tables giving some of these results are not as consistent in form as might be desired, but the general conclusions are quite clear. By far the greatest proportion of the food is insects, this being particularly the case outside the breeding season. The appearance of great numbers of any particular species is immediately reflected in the food: those most commonly taken were crane-flies (*Tipula*), earwigs (*Forficula auricularia*), ground-beetles (*Pterostichus madidus*), dor-beetles (*Geotrupes stercorarius*) and cockchafers (*Melolontha vulgaris*), all but *Geotrupes* notified as pests by the Ministry of Agriculture.

Birds and small mammals were taken in some numbers during the nesting season, starlings (*Sturnus vulgaris*), sparrows (*Passer domesticus*) and Turdidae being the commonest of the former, and house mice (*Mus musculus*), wood mice (*Apodemus*), field voles (*Microtus*), bank voles (*Clethrionomys*) and shrews (*Sorex*) the commonest of the latter.

Apart from these, frogs, lizards, rabbits, rats, various species of small birds, earthworms, woodlice, spiders, millipedes, snails and Lepidopteran eggs were recorded in some numbers.

A special enquiry was conducted during the second year into the food of birds that were breeding near poultry farms or game preserves, which showed that this form of food was negligible. Tests proved that such food would appear in the pellets of captive little owls fed with chicks.

Cognate biological points are dealt with, showing that the species is largely a crepuscular or nocturnal feeder (hence game and poultry would be little affected), that it is primarily a ground feeder, that it does not "store" food, and that it does not kill and leave carcases in order to collect the burying beetles later. This part of the report is mixed up with considerable quotation of opinion, and is not perhaps set out to the best advantage.

The work as a whole however is thorough and authoritative, the plates are to the point, and the pains taken by Miss Hibbert-Ware in the analysis may serve as an example to others.

H. N. SOUTHERN.

SHORT REVIEWS

Cynthia Longfield (1937). *The dragonflies of the British Isles.* 220 pp. and 260 illustrations. F. Warne and Co. Ltd., Bedford Court, Bedford Street, London, W.C. 2 and 381 4th Avenue, New York. Price 7*s.* 6*d.*

This book is a useful addition to the slowly growing list of competent entomological handbooks. It contains a key to the identification of the species of Odonata for field use, information on their collection and preservation, a lucid and interesting account of life histories, general biology, ecology and palaeontology. Descriptions of individual species, imagines and nymphs, are given, together with notes on habits, times of appearance and distribution. There is also a section on the classification of Odonata, in which families and genera are described, chiefly according to wing structure. Finally the book contains a glossary, a pronunciation guide to Greek and Latin names, a list of the times of first appearance of species, a check list of all British species and a complete index. There is an abundance of illustrations, both photographs and drawings. It seems a pity that in the set of drawings of wings, for purposes of comparison, some should be of left and others of right wings. The photographs of imagines and nymphs are admirable.

The key to species is intended, and is only suitable for, field work, being based chiefly on colour differences and therefore inadequate for identification of preserved material. A feature of the book which is not entirely successful is the attempt to provide popular names for species. The distinction between "dragonflies" for the Odonata as a whole and "dragonflies" for the Anisoptera is confusing. The Zygoptera are distinguished by their old name of "damsel flies". The book, though intentionally popular, should prove of great value both to entomologists and ecologists.

JOHN FORD.

Victor E. Shelford (1937). *Animal communities in Temperate America, as illustrated in the Chicago Region: a study in animal ecology.* The Geographic Society of Chicago, Bull. No. 5: 1–368, 315 illustrations. The University of Chicago Press, Illinois. Price $3.

This monograph, originally published in 1913, is reprinted here without substantial change, except for the addition of some later references to the literature on the ecology of the region. All zoological libraries should have it; and many ecologists will be delighted to be able to obtain at the reasonable price copies of a "classical" work which had become rare in book-shops. But more than that: in re-reading it they will be able to recall some of the freshness and sense of space and grandeur that the field work of primary ecological survey can give, and which is so easily lost under the later burdens of indoor sorting, noting, identification and the general deluge of detail—not to mention the close intricacy of experimental studies and the nightmare of literature. Prof. Shelford's original survey was a remarkable feat of industry and organization, as well as being a pioneer research. Its clear presentation is enhanced by the abundance of illustrations, which give reality to the Latin names of animals mentioned. There is, as yet, no parallel survey in Great Britain which comes anywhere near the scope of this comprehensive account of the Chicago country ecosystem.

CHARLES ELTON.

NOTICES OF PUBLICATIONS ON ANIMAL ECOLOGY

This series of notices covers most of the significant work dealing with the ecology of the British fauna published in British journals and reports. Readers can aid the work greatly by sending reprints of papers and reports to the Editor, *Journal of Animal Ecology*, Bureau of Animal Population, University Museum, Oxford.

Copies of these abstracts are issued free with the *Journal*. They can also be obtained separately in stiff covers, printed on one side of the page to allow them to be cut out for pasting on index cards, by non-subscribers, from the Cambridge University Press, Bentley House, N.W. 1, or through a bookseller, price 3*s*. 6*d*. per annum post free, (about 300 notices, in two sets, May and November).

Abstracting has been done by H. F. Barnes, J. R. Carpenter, D. H. Chitty, C. Elton, F. C. Evans, J. Ford, and B. M. Hobby.

1. ECOLOGICAL SURVEYS AND HABITAT NOTES

(*a*) Marine and brackish

See also **9, 13, 46, 112**

1. Crawford, G. I. (1937). "The fauna of certain estuaries in West England and South Wales, with special reference to the Tanaidacea, Isopoda and Amphipoda." J. Mar. Biol. Ass. U.K. 21: 647–62.

Estuaries of the Plym and Exe, Taw, Camel, Towy, Tamar, Tavy and Lynher were examined and the Crustacean fauna analysed. Notes and literature on brackish-water Crustacea in England, together with a discussion of the English species of *Gammarus*.

2. Anon. (1937). "Excessive marine growth in Shoreham Harbour." Nature, Lond., 140: 966.

Warm water in the Southwick basin of this harbour is apparently the chief cause for extreme growth of a Polychaete worm resembling *Hydroides norvegica*, but possibly new to science.

3. Fisher, N. (1935). "The marine Mollusca of Magilligan. Co. Derry." J. Conch. 20: 168–75.

List of 162 species of shells thrown up on Magilligan strand, with a topographical description of the district.

4. Crawford, G. I. (1937). "Notes on the distribution of burrowing Isopoda and Amphipoda in various soils on the sea bottom near Plymouth." J. Mar. Biol. Ass. U.K. 21: 631–46.

Collections made with a fine-meshed dredge and a D-net. Distributional notes are given on species inhabiting intertidal areas as well as below the low-water mark. Full Appendices of collecting stations, soil types and fauna lists.

5. Raitt, D. S. (1937). "On the occurrence of *Gammarus* in Scottish coastal, brackish and inland waters." Scottish Nat.: 155–61.

A review of the literature concerning the presence of the four species of this Amphipod.

(*b*) Freshwater

See also **5, 13, 37, 46, 53, 79**

6. Hamilton, D. (1937). "Grebes and other birds at Linlithgow Loch." Scottish Nat.: 129–30.

Observations on grebes in the winter of 1936–7, and some other records.

7. Serle, W. (1937). "The avifauna of Duddingston Loch, Midlothian." Scottish Nat.: 35–45.

A review of the changes in this 19 acre Loch, 1927–36. Ninety-nine birds are discussed and a table concerning the Sept. 1934 to April 1935 weekly abundances of ten species of ducks is given.

8. Eltringham, W. (1937). "A record year on the Crawcrook Pond." Vasculum, 23: 151.

33 waterhens, 20 little grebes and 5 coots were hatched on the two ponds in 1937. The total (58) is the largest in the history of the pond. In a space of 300 by 80 yd. over 200 young terrestrial birds were hatched.

9. Pyefinch, K. A. (1937). "The fresh and brackish waters of Bardsey Island (North Wales): a chemical and faunistic survey." J. Anim. Ecol. 6: 115–37.

32 species found and their distribution discussed in relation to chemical and physical conditions; a special account is given of the ecology of the flatworm *Procerodes ulvae*.

10. Humphries, C. F. & Frost, W. E. (1937). "River Liffey survey. The Chironomid fauna of the submerged mosses." Proc. R. Irish Acad. B, 43: 161–81.

Two stations, one acid and the other alkaline, on moss and liverwort-covered gravel at Ballysmuttan and Straffan, I.F.S., showed that the dominant mosses were *Fontinalis squamosa*, *F. antipyretica*, and *Eurynchium rusciforme*. 4 subfamilies of Chironomids, including 24 genera and 36 "types" were found. 13 genera and 22 types were common to both stations (at which quantitative samples were taken); 4 new types are described. Orthocladiariae constituted about 95% of the specimens at each station. Seasonal fluctuation in numbers was similar in both stations, maxima occurring in July or August and November or February; minima in May or June and September or October. This study formed part of an investigation of the food ecology of the brown trout (*Salmo trutta*).

11. Rushton, W. (1937). "A further biological study of the River Usk." Publ. Usk Board of Conservators (October): 1–23.

A rather casual survey of some of the animal and plant life of the river and its tributaries, with special reference to the occurrence of trout and other fish, fish foods and sewage effluents.

12. Pentelow, F. T. K. (1935). "Notes on the distribution of the larvae and pupae of *Simulium* spp. in the River Tees and its tributaries." Parasitology, 27: 543–6.

The distribution of five species is described. Suggested factors influencing distribution are geological structure, distribution of water plants and hardness of water. These blood-sucking flies only breed in fast running streams.

(*c*) Land

See also **42, 43, 45, 75, 106**

13. Tattersall, W. M. (editor) and others (1936). "Glamorgan County History. Vol. 1. Natural History." Wm. Lewis (Printers) Ltd., Cardiff. Price 25*s*.

A survey of the geology, botany, and zoology of the county; with the exception of seaweeds and birds, marine life is omitted. (Reviewed in J. Anim. Ecol. (1937) 6: 386–7.)

14. Watt, H. Boyd (1937). "On the wild goat in Scotland." With supplement: "Habits of wild goats in Scotland", by **F. Fraser Darling**. J. Anim. Ecol. 6: 15–22.

A review of the known history and distribution of goats which have become feral. The supplement contains first-hand field observations in West Ross-shire.

15. Lack, D. & Venables, L. S. V. (1937). "The heathland birds of South Haven Peninsula, Studland Heath, Dorset." J. Anim. Ecol. 6: 62–72.

An ecological survey of the habitats and distribution, including a section on the effects of burning on nesting. Also a discussion on the five most abundant birds. (See also **48**.)

16. Witherby, H. F. & Nicholson, E. M. (1937). "Supplementary notes on the distribution and status of the British willow-tit." British Birds, 31: 104–5.

This species, recorded first in 1900, was formerly confused with the marsh tit. Data obtained on the distribution and relative abundance of these species, up to the present, are recorded. The marsh tit is unknown in Scotland, but the willow tit is known as far north as Ross, Moray and Inverness. Further information is needed.

17. Barnes, H. F. (1937). "Insects and other pests injurious to the production of seed in herbage and forage crops." Herbage Publ. Ser., Imp. Bur. Plant Genetics, Bull. 20: 1–31 and i-iii.

A summary of the available information concerning some of the insect and other pests injurious to the production of seed in grasses and legumes. Although no references have been inserted, all the facts given here have been checked in the light of the most recent research. 127 spp. of insects (89 genera) and 46 spp. of plants are considered in the 3-page index; while the more important pests fill the main text. It is not always clear whether the information applies to the British Isles.

18. Donisthorpe, H. St J. K. (1937). "A preliminary list of the Coleoptera of Windsor Park." Ent. Mon. Mag. 73: 167–76; 237–46; 273–4.

19. Laing, F. (1936). "*Anoncodes melanura* L. as a destructive insect." Ent. Mon. Mag. 72: 15–17.

Notes on the presence of this beetle in London. The larva is a wood borer, often, though not always, in wood placed near water. Further reference in **K. G. Blair**, *ibid.* 72: 17–18; **R. C. Fisher**, *ibid.* 72: 41–2; **J. J. Walker**, *ibid.* 72: 43.

20. Fisher, R. C. (1937). "Studies of the biology of the death-watch beetle, *Xestobium rufovillosum* De G. I. A summary of past work and a brief account of the developmental stages". Ann. Appl. Biol. 24: 600–13.

21. Edwards, T. G. (1937). "Record of Macrolepidoptera found in a London garden." Ent. Rec. 49:101–3.

A surprisingly long list for such a closely built-up area.

22. Barnes, H. F. (1937). "The hollyhock seed moth (*Platyedra malvella* Hübn.), together with notes on the distribution of *Apion radiolus* Kirby and an associated *Clinodiplosis* species.". Ann. Appl. Biol. 24: 589–99.

This moth is limited to the S.E. counties of England. The *Apion* and gall midge are generally distributed throughout England, while the latter occurs also in Wales and Ireland. Degrees of infestation by the moth in 1934 and 1935 averaged 65% of the seed heads and ranged up to 97%. An Ichneumonid parasite *Angitia rufipes* was reared.

23. Holborn, J. M. (1937). "Infestation of willows in Suffolk." Entomologist, 70: 211–2.

Hyponomeuta rorella parasitized by the Ichneumonidae *Herpestomus brunnicornis* and *Angitia armillata* and by the Chalcid *Ageniaspis fuscicollis*.

24. Barnes, H. F. (1937). "The Asparagus miner (*Melanagromyza simplex* H. Loew) (Agromyzidae; Diptera)." Ann. Appl. Biol. 24: 574–88.

Includes notes on emergence, mating, oviposition, life cycle and local abundance of this fly during two years. Three parasites are recorded: the Braconid *Dacnusa ?bathyzona*; a Pteromalid *Sphegigaster* sp.; and a Eulophid *Pleurotropis epigonus*.

25. Varley, G. C. (1937). "The life-history of some Trypetid flies, with descriptions of the early stages (Diptera)." Proc. R. Ent. Soc. Lond. A, 12: 109–22.

The Trypetid flies whose life-histories are described in this paper were mostly found during an ecological study of the insect community in the flowerheads of the black knapweed, *Centaurea nigra*.

26. Spooner, G. M. (1937). "Hymenoptera Aculeata from the North-west Highlands." Scottish Nat.: 15–23.

Records for 20 species with notes on geographic distribution; ants not included.

27. Cowley, J. (1937). "Notes on British Odonata in 1936." Entomologist, 70: 221–2.

Emergence dates of dragonflies in various localities.

28. Rawlinson, R. (1937). "The occurrence of the Amphipod *Talitrus dorrieni* Hunt in Co. Galway, Ireland." Ann. Mag. Nat. Hist. 20: 589–92.

This terrestrial species, hitherto known only from Tresco Island, Scilly Isles, has now been found, in a slightly variant form, in Galway. Some notes are given on the pigmentation of Crustacea.

29. Wilson, G. Fox (1937). "The root-knot eelworm, *Heterodera marioni* (Cornu) Goodey, and its relation to plants growing outdoors in the British Isles and in certain European countries." J. Roy. Hort. Soc. 62: 336–46.

In Great Britain and other countries with a temperate climate this nematode (syn. *H. radicicola* Greef) is primarily a pest of glasshouse plants, such as tomatoes, cucumbers and Begonias. In warmer climates it is a very serious pest in outdoor crops, having been recorded from over a thousand species of plants, including weeds that form reservoir hosts. It has been recorded out of doors in the British Isles from 15 wild and cultivated plants, of which an annotated list is given. The life history etc. are also described.

30. Goodey, T. (1937). "On some new hosts of the stem eelworm, *Anguillulina dipsaci*." J. Helminth. 15: 215–20.

Parsnip (*Pastinaca sativa*) infected with onion strain; *Primula pulverulenta* and *P. polyantha*, source of infection unknown; swine-cress (*Coronopus ruellii*), infected from Narcissi.

31. Johnson, L. R. (1936). "A note on the occurrence of *Anguillulina dipsaci* (Kühn, 1858) on certain weeds, including a new host record." J. Helminth. 14: 233–5.

Cleavers (*Galium Aparine*), a new host record for this eelworm. Observations suggest this weed and chickweed (*Stellaria media*) may be the intermediate hosts carrying over the parasite from infested oats to beans in the next year.

32. Goodey, T. (1937). "Two methods of staining nematodes in plant tissues." J. Helminth. 15: 137–44.

Substitutes for the expensive osmic acid technique.

(*d*) Small islands

See also **65**

33. Morrison-Scott, T. C. S. (1937). "A note on the distribution of the two shrews found in Jersey." J. Anim. Ecol. 6: 284–5.

Evidence based on owl pellet analyses (which disclosed eight kinds of mammal and two birds) that *Sorex araneus fretalis* lives inland and *Crocidura russula* near the shore.

34. Dowdeswell, W. H. (1937). "Further notes on the Lepidoptera of Cara Island." Entomologist, 70: 169–75.

Includes notes on *Xylophasia monoglypha* being eaten by rats, and its population numbers in relation to melanism.

35. Harrison, G. Heslop (1936). "Notes from the Hebrides." Entomologist, 69: 71–2.

Lepidoptera and Coccids from Mull, Barra, Canna, Raasay and Scalpay: on heather, spruce, *Salix* and mosses.

36. Heslop-Harrison, G. (1936). "A contribution to our knowledge of the Psyllidae of the Hebrides." Ent. Mon. Mag. 72: 48–51.

28 species are now recorded from 12 islands, including Skye, Mull, S. Uist, Barra and S. Rona. They are listed, with their host plants and localities.

37. Harrison, G. Heslop (1936). "Coleoptera from the Outer Hebrides, with an account of a new British species, *Deronectes canariensis* Bedel." Ent. Mon. Mag. 72: 52–3.

Beetles from S. Uist and Barra. *D. canariensis* is an aquatic beetle formerly known from the Canaries.

38. Harrison, J. W. Heslop & Peacock, A. D. Edited by (1937). "The natural history of the Island of Raasay and of the Adjacent Isles of South Rona, Scalpay, Longay, and Fladday." Scottish Nat. (for pages see below).

(In this abstract the islands are referred to by their initial letters)

"I. The vertebrates other than birds and fishes." By **J. W. Heslop Harrison.** Pp. 61–3.

Amphibia: *Molge vulgaris* (R, S, SR), *M. palmata* (R), *Bufo vulgaris* (R, S), *Rana temporaria* ("everywhere"). Reptilia: *Lacerta vivipara* (R, S), *Viperus berus* (R, S) in inverse abundance. Mammalia: *Sorex araneus* (R), *Pipistrellus pipistrellus* (R), *Mustela nivalis* (R), *Rattus norvegicus* (R), *Mus musculus* (R), *Oryctolagus cuniculus* (R, S, SR, L, F, and Guillamon I.), *Lepus timidus* (R), *Cervus elaphus* (about a dozen, formerly 600 on R; about 80 on S including colonists from Skye). Also two species of seals and a porpoise. On Longay, rabbits have almost eliminated grass species, leaving strong associations of unattacked plants like *Solidago Virgaurea*. They have also driven out much of the original vegetation on Guillamon I. (Effect of sheep is not commented upon).

"II. The land and freshwater Mollusca." By **G. Heslop Harrison.** Pp. 64–7.

Probably fairly comprehensive collection, from three summers' work: 36 species from R, 20 from S, 12 from SR, three from L, and five from F. Some general habitat notes are given.

"III. Thysanoptera found on Raasay and Scalpay." By **G. D. Morison.** Pp. 67–71.

12 species of thrips. This note includes some biological information about the species on the mainland, mainly relating to life histories.

"IV. Spiders and allied groups." By **J. E. Hull** and **J. W. Heslop Harrison.** Pp. 107–13.

98 species of spiders, 8 Phalangids, and one pseudoscorpion, with a few vague habitat notes. There is a marked southern element in the spider fauna.

"V. The Eriophyidae, or gallmites." By **J. W. Heslop Harrison.** Pp. 135–7.

30 species, partly identified from the galls alone.

"VI. Hymenoptera Symphyta on the Island of Raasay." By **F. Greenshields.** Pp. 138–44.

36 species of sawflies, of which ten had previously been found also on South Rona. Host plants are given. Ichneumonid *Rhyssa persuasoria* parastic on *Sirex* in pine trunks, was also found, on R.

"VII. The variation of the Lepidopterous genus *Triphaena* in Raasay, South Rona, and Scalpay, with special reference to *T. ianthina* Esp." By **J. W. Heslop Harrison.** Pp. 169–72.

Wide gradation was found in varieties thought to be distinct on the mainland.

39. Various Authors (1937). "St Kilda papers." Oxford Univ. Press. (Not on sale.)

A collection of already published papers on the ecology of St Kilda by members of the Oxford and Cambridge student expedition of 1931. (Reviewed in J. Anim. Ecol. (1937) 6: 392.)

2. GENERAL REPORTS AND TAXONOMIC STUDIES OF USE TO ECOLOGISTS

See also Section 4, for parasites

40. Bracher, R. (1937). "Ecology in town and classroom." 96 pp. J. W. Arrowsmith, Ltd., Bristol. Price 2*s.* 6*d.*

The plant ecology of streets, waste ground, building sites, etc. (Reviewed in J. Anim. Ecol. (1937) 6: 393.)

41. Anon. (1937). "Eleventh Report of the Committee on the nomenclature and records of occurrences of rare birds in the British Isles, and on certain necessary changes in the nomenclature of the B.O.U. list of British birds." Ibis: 396–402.

Additions to the list of British birds, new British races and changes of name and status.

42. Massee, A. M. (1937). "The pests of fruits and hops." 294 pp. Crosby, Lockwood & Son, Ltd., London. Price 15*s.*

Includes lists of insects attacking various fruit trees and shrubs. (Reviewed in J. Anim. Ecol. (1937) 6: 391.)

43. Chrystal, R. N. (1937). "Insects of the British woodlands." 338 pp. Frederick Warne & Co., Ltd., London & New York. Price 7*s.* 6*d.*

An account of the ecology of British forest pests. (Reviewed in J. Anim. Ecol. (1937) 6: 390–1.)

44. Jepson, W. F. (1937). "Observations on the morphology and bionomics of *Serica brunnea*, L., with notes on allied chafer pests. Part I. The morphology of the larva of *Serica brunnea*, L." Bull. Ent. Res. 28: 149–65.

45. Hodson, W. E. H. (1937). "On the synonymy and biology of the strawberry aphis, *Capitophorus fragariae*, Theo. (1912)." Bull. Ent. Res. 28: 409–16.

Reference is made to the proved capacity of Aphides of the genus *Capitophorus* to transmit virus disease among strawberries, and attention is drawn to the confusion existing as to the actual synonymy of the insect principally concerned. The incidence of the aphis in the field, and the biology as observed in field and laboratory are discussed.

46. Crawford, G. I. (1937). "A review of the Amphipod genus *Corophium*, with notes on the British species." J. Mar. Biol. Ass. U.K. 21: 589–630.

A systematic review of this shallow-water, tube-building genus. A complete bibliography accompanies the discussion of each species; notes emphasize distributional, ecological and morphological aspects. Three new species are described, with figures. The review is supplemented by a key to the valid species.

3. ANIMAL BEHAVIOUR AND THE ACTION OF ENVIRONMENTAL FACTORS

See also **2, 11, 15, 69, 103, 110, 112, 142**

47. Lack, D. (1937). "The psychological factor in bird distribution." British Birds, 31: 130–6.

Although environment influences distribution, psychological factors are no less important. Birds are guided in their selection of habitat by features perhaps visually prominent but not essential to their existence. The recognition of such features by the investigator is difficult, but examples of psychological reactions which affect choice of nesting sites and song perches and influence feeding habits, etc., indicate their undoubted importance in bird distribution.

48. Venables, L. S. V. (1937). "Bird distribution on Surrey Greensand heaths: the avifaunal-botanical correlation." J. Anim. Ecol. 6: 73–85.

Discussion on heath succession following fire, and factors limiting bird distribution and breeding territories. (See also **15**.)

49. T[emperley], G. W. (1937). "Disabled birds." Vasculum 23: 150.

Comments on the unusual number of disabled birds seen during the summer of 1937.

50. Savage, R. M. (1937). "The ecology of young tadpoles, with special reference to the nutrition of the early larvae of *Rana temporaria temporaria* Linn., *Bufo bufo bufo* Linn., and *Bombina variegata variegata* Linn." Proc. Zool. Soc. Lond. A: 249–60.

The early larvae of these species do not derive noticeable quantities of food material from their own egg-envelopes, yet they seem to develop faster when allowed to remain on the envelopes. Particulate feeding is impossible in these early stages, as the septum closing the mouth is still entire. The gradual disappearance of the envelopes is probably due to bacterial action.

51. Atkins, W. R. G. (1938). "British fisheries, phosphate and the solar radiation constant." Nature, Lond., 141: 77–8.

Since 1923 there has been a decrease in the phosphate content of the water of the English Channel, accompanied by a decrease of plankton abundance and in turn by a shortage of fish. This coastal water is replenished with phosphate only by the influx of large masses of water from the Atlantic, such as occurred in 1921. This was also the year for an exceptionally high solar radiation and the connexion between the two facts is suggested here as a reasonable speculation.

52. Rosenberg, M. (1937). "Algae and trout: a biological aspect of the poor trout season in 1937." Salm. Trout Mag. No. 89: 313–22.

The exceptionally poor trout season of 1937 in the Scottish lochs was correlated with dense surface growths of Algae, hindering the rise of fish and causing them to seek the deeper waters. These Algal growths are dependent upon a large amount of organic matter, such as was presumably supplied by the abnormally high rainfall in January and February, 1937.

53. Garner, J. H., Brown, F. M. & Lovett, M. (1936). "Report upon chemical and biological survey of the River Holme." West Riding of Yorkshire Rivers Board. 44 pp., 21 tables at the end, 3 maps.

A monthly quantitative survey (March 1933 to July 1934) with 13 stations was made on the 12 mile long stream, which has its origin in the Pennine chain. Pollution occurs from six wool-textile mills and exerts effects on the fauna through the changing of ecological conditions. Certain parts of the stream bed showed partial recovery from the cumulative effects of pollution, but no appreciable change in the fauna was found. It is suggested that certain trade effluents exercise a greater influence on the normal biological conditions of a stream than do sewage effluents of apparently similar impurity. "The standards suggested by the Royal Commission on Sewage disposal are not sufficiently stringent to meet the requirements of the particular case investigated, as they are based entirely on limiting amounts of suspended solids without any reference to biological purification.... However it is admitted that application of biological methods of purification to trade effluents would be both difficult and costly." Tables of faunal and chemical data during the 16 monthly collections are presented.

54. Day, W. R. & Peace, T. R. (1937). "Spring frosts." Bull. Forestry Comm. 18: 1–131. H.M. Stationery Office, London. Price 2*s.* 6*d.*

Full account of research on frost incidence, 1927–35, but especially the late frosts of May 1935, which did wide damage. Refers primarily to meteorology, topography and tree damage, but is of general importance for animal ecology. (Reviewed in J. Anim. Ecol. (1937) 6: 391–2.)

55. Tate, P. & Vincent, M. (1936). "The biology of autogenous and anautogenous races of *Culex pipiens* L. (Diptera: Culicidae)." Parasitology, 28: 115–45.

Artificial lighting inhibited hibernation in an anautogenous race. The females attack birds more readily than man. European autogenous races have been maintained in the laboratory without blood meals through 45–49 generations, lasting over 3 years. Stenogamy and autogeny are hereditary characters.

56. Marshall, J. F. & Staley, J. (1935). "Some adult and larval characteristics of a British "autogenous" strain of *Culex pipiens* L." Parasitology, 27: 501–6.

Certain strains of this mosquito are able to mate in confined spaces (stenogamy), to breed throughout the year and to lay fertile eggs without a previous blood meal (autogenous, in distinction from anautogenous strains which do require a meal of blood before fertile eggs are produced). The morphological characters of an autogenous, stenogamic race found at Hayling Island, Hampshire, are described.

57. Ilse, D. (1937). "New observations on responses to colours in egg-laying butterflies." Nature, Lond., 140: 544–5.

Experiments with *Pieris brassicae* showed that egg laying ♀♀ distinctly selected a continuous range from "emerald green" (Ostwald colour No. 22) to "oxide blue" (No. 16), to the neglect of yellow and pure blue. Comparison with colour selection findings for other insects shows a greater degree of discernment of colours in the cabbage white. Selection of purple here appears to be caused by simultaneous colour contrasts.

58. Laing, J. (1937). "Host-finding by insect parasites. 1. Observations on the finding of hosts by *Alysia manducator*, *Mormoniella vitripennis* and *Trichogramma evanescens*." J. Anim. Ecol. 6: 298–317.

Alysia and *Mormoniella* are attracted to an environment likely to contain their hosts by qualities of the environment itself, independent of the presence of hosts.... *Trichogramma* is able to perceive its hosts (eggs of *Sitotroga*) by the sense of sight.

59. Jackson, D. J. (1937). "Host-selection in *Pimpla examinator* F. (Hymenoptera)." Proc. R. Ent. Soc. Lond. A, 12: 81–91.

This ichneumon is an internal parasite of Lepidopterous pupae. A long list of recorded hosts is given and the life-history summarized. The development of the larva in hosts of different sizes is discussed. Differences were observed in the reactions of different females to pupae of the same species, some individuals readily ovipositing in naked pupae, others only in pupae within real or artificial cocoons.

60. Hobson, R. P. (1937). "Sheep blow-fly investigations. V. Chemotropic tests carried out in 1936." Ann. Appl. Biol. 24: 627–31.

Account of 42 organic substances used as repellents.

61. Franklin, M. T. (1937). "The survival of free larvae of *Heterodera schachtii* in soil." J. Helminth. 15: 69–74.

This nematode survives many years encysted in soil with no host plant. Experiments show that free living larvae can survive at least 9 months in plant free soil. This must be taken into account in control methods which involve the artificial hatching of cysts.

62. Gibbons, S. G. (1937). "Variations in Copepod development." Nature, Lond., 140: 1064–5.

The suggestion is made that the suppression of stages (from six to five) in the nauplius life of *Eucalanus elongatus* is correlated with a lowering of water temperature.

63. Saunders, J. T. & Ullyott, P. (1937). "Thermo-electric apparatus for limnological research." Int. Rev. Hydrobiol. 34: 572–7.

As a time-saving device, electrical apparatus has obvious advantages for limnology. The resistance method of measuring temperature is cumbersome and difficult to manipulate, and to replace it a thermocouple thermometer with a direct reading scale is described. Hot and cold junctions are connected by copper and constantan wires; the cold junction is maintained at 0° C. by ice in a thermos flask, while the hot junction is in contact with the water to be tested. This apparatus is enclosed in a strong watertight compartment and lowered to the desired depth. A galvanometer introduced into the circuit measures the E.M.F. which bears a linear relationship to the temperature. Thus a direct reading may be had from this apparatus, which is both light and inexpensive. Features of construction and calibration are dealt with thoroughly.

4. PARASITES

See also **23, 24, 38** (VI), **58, 59, 60, 110**

64. Keay, G. (1937). "The ecology of the harvest mite (*Trombicula autumnalis*) in the British Isles." J. Anim. Ecol. 6: 23–35.

Distribution in Britain, hosts, records of Trombiculae on man, and the human diseases carried are discussed. *Trombicula autumnalis* can over-winter on rabbits and bank voles.

65. Thompson, G. B. (1937). "On some parasites obtained from birds on Skokholm Island." British Birds, 30: 317–8.

Ecto-parasites of gannet, Manx shearwater and meadow pipit collected from birds trapped for ringing.

66. Thompson, G. B. (1937). "A list of the Denny collection of Mallophaga in the British Museum (Natural History) and of their hosts." Ann. Mag. Nat. Hist. 19: 74–81.

The material described in Denny's "Monographia Anaplurorum Britanniae", 1842. A list of 117 species, with their type hosts and other hosts recorded by Denny.

67. Gimingham, C. T. (1937). "*Crataerina pallida* Latr., a parasite of the swift (Diptera)." Proc. R. Ent. Soc. Lond. A, 12: 135.

More than twenty specimens of the Hippoboscid fly, *Crataerina pallida* Latr., were taken on a swift that fell to the ground in an exhausted condition at Harpenden in June, 1934. This large number of parasites infesting a single bird would seem to be unusual and the loss of blood due to their feeding may have led to its fall.

68. Thompson, G. B. (1937). "The parasites of British birds and mammals. XVI. Records of Ixodoidea (Ticks)." Ent. Mon. Mag. 73: 160–2.

Ixodes ricinus on red grouse, rabbit, mountain hare, common lizard, dog, cow and lambs. *I. hexagonus* on blue tit and wren. *I. canisuga* on house sparrow and *I. putus* on gannet.

69. MacLeod, J. (1935). "*Ixodes ricinus* in relation to its physical environment. III. Climate and reproduction." Parasitology, 27: 489–500.

Humidity and temperature in relation to oviposition and development. Humidity is the more important, save at extreme temperatures. The lower limit of humidity for development is about 80% R.H. The limits of temperature and humidity are not the same for development and oviposition, the latter being the lower.

70. Radford, C. D. (1936). "Notes on the mites of the genus *Myobia*. Part III." Northw. Nat. 11: 34–9.

Descriptive notes and drawings of 4 species. A new muskrat mite is named *Myobia zibethicalis*.

71. Radford, C. D. (1936). "Notes on mites of the genus *Myobia*. Part IV." Northw. Nat. 11: 144–51.

Includes drawings of 4 species, with descriptive notes. A new species, *Myobia blairi* is announced. An Appendix lists the species of *Myobia* and their hosts.

72. Thompson, G. B. (1937). "The parasites of British birds and mammals. XVII. A bibliography of the previous records of Nycteribiidae, together with additional records and notes." Ent. Mon. Mag. 73: 274–8.

73. Warwick, T. (1937). "The occurrence of disease among muskrats (*Ondatra zibethica*) in Great Britain during 1934." J. Anim. Ecol. 6: 112–4.

Cases of lung disease and tubercular spleen are cited as being in part responsible for the 1934 decrease in muskrat numbers.

74. MacLeod, J. (1937). "The species of Diptera concerned in cutaneous myiasis of sheep in Britain." Proc. R. Ent. Soc. Lond. A, 12: 127–33.

Until recently it had generally been accepted that "strike" of sheep was due, so far as Britain is concerned, to only one species of fly, *Lucilia sericata*. This finding is challenged: three other species, *L. ceasar*, *Calliphora erythrocephala*, and *Phormia terrae-novae*, were found to occur in Scotland (27 out of 68 cases). Evidence supports the contention that *L. ceasar* and *P. terrae-novae* are primary striking flies, and *C. erythrocephala* a true secondary striking fly.

75. Haddow, A. J. & Thompson, R. C. Muirhead (1937). "Sheep myiasis in south-west Scotland, with special reference to the species involved." Parasitology, 29: 96–116.

Dipterous larvae from cases of myiasis in Ayrshire, Arran, and Argyllshire were bred out and showed that six spp. in addition to the usual *Lucilia sericata* were responsible for secondary myiasis; of these, four are new records for which records are given. The species of blowflies studied were found to hibernate as prepupae, pupation taking place in April or May. The "fly season" lasted approximately from May–September, reaching its maximum in July–August. The flies were found most abundantly in low-lying, sheltered ground, especially where much bracken was present.

76. Fenwick, D. W. (1937). "A census of intestinal parasites of lambs in South Wales." J. Helminth. 15: 169–76.

Tables are given showing the incidence of infection with parasites in different sections of the gut, and the seasonal changes in parasite population density, in lambs under one year old. Of nine worms recorded, four are confined to particular regions of the gut, the remaining five showing greater plasticity. In addition to chemical and physical factors within the gut, external conditions, by their effect on the infective stage, would appear to control the position taken up by the mature parasite.

77. Clapham, P. A. (1936). "Further observations on the occurrence and incidence of helminths in British partridges." J. Helminth. 14: 61–8.

Two cestodes and one trematode are newly recorded from *Perdix perdix*. Incidence of helminth disease in 1935 was low, owing to dry weather. Death from strongylosis is most frequent between October and December and again in April and May. It is suggested that conditions are most favourable in spring and autumn for infection, i.e. damp and warm, whereas in summer drought is a limiting factor and in winter, cold. Factors influencing cestode infestation in partridge and grouse are also discussed.

78. Clapham, P. A. (1937). "On some lesions associated with helminths in birds of economic importance." J. Helminth. 15: 49–52.

Recent opinion tends to discount the danger of helminth infestation. This paper describes pathological conditions in various gallinaceous birds which were undoubtedly due to helminths.

79. Rushton, W. (1937). "Blindness in freshwater fish." Nature, Lond., 140: 1014.

Blindness in a number of yearling rainbow trout was due to the presence of larval forms of the trematode *Diplostomum volvens* Nord. in the lens. This is apparently a new record for Britain. The life history of the parasite is given briefly and shows the alternate host to be a water bird, usually a gull. A later note (1938, Nature, 141: 289) records the same condition in rainbow trout and roach. The disease occurs in Europe, where the parasite is known to have a further intermediate stage in Molluscs.

80. Morris, K. R. S., Cameron, E. & Jepson, W. F. (1937). "The insect parasites of the spruce sawfly (*Diprion polytomum*, Htg.) in Europe." Bull. Ent. Res. 28: 341–93.

A severe outbreak of the spruce sawfly (*Diprion polytomum*) in Eastern Canada led to a request to Farnham House Laboratory to investigate, and if possible collect and export, the parasites of this insect in its native home in Europe. Work started in 1932 and it was found that *D. polytomum* was a comparatively rare insect in Europe, though widely distributed. It is heavily parasitized, 31 species of Hymenopterous and Dipterous parasites having been found up to the present. Nearly 28,000,000 parasitized cocoons and eggs of this and other species of *Diprion* have been collected and despatched from Europe, and work is still continuing. Previous to the present work only 13 species of parasites, a list of which is given, were recorded from this host. Of the 31 species now known, 15 are primary, five can be primary or secondary, and nine secondary only; in two cases the status is not known. Descriptions of all the species are given and in the case of the obligatory and facul-

tative primaries, the biology and immature stages are also described and notes added on their suitability for introduction into Canada. Keys are given to the adult parasites and to the larval stages of the primary and facultative primary parasites. Some practical notes also, including methods of accelerating the emergence of parasites in winter and methods of preparing parasite larvae for examination and identification.

81. Morley, C. (1936). "Notes on Braconidae. XV. Microgasterinae." Entomologist, 69: 39–42, 64–7, 90–4, 115–9, 140–2.

Keys to species, with some notes on hosts and distribution of these parasitic Hymenoptera.

82. Salt, G. (1936). "Miscellaneous records of parasitism. I." Ent. Mon. Mag. 72: 9–12.

Hymenopterous parasites of *Syrphus balteatus* and *S. auricollis* (Diptera) and of *Cephus pygmaeus*, the wheat stem sawfly, with information on the incidence of parasitism.

83. Mansbridge, W. (1937). "Fungus attacking larvae and pupae of Lepidoptera." Entomologist, 70: 187.

Issaria farinosa.

84. Patten, R. (1935). "The life history of *Merocystis kathae* in the Whelk, *Buccinum undatum*." Parasitology, 27: 399–430.

A Coccidian parasite in the kidney of the whelk. The stages within the primary host are described. The intermediate host is not known, but it is possible that it is a crab or other Crustacean.

85. Jepps, M. W. (1937). "On the Protozoan parasites of *Calanus finmarchicus* in the Clyde Sea Area." Q. J. Micr. Sci. 79: 589–658.

A study of the parasites of this Copepod usually considered to be Protozoa showed the presence of *Blastodinium*, *Synidinium*, some Gregarines (*indet.*), a new ectoparasitic Ciliate (*Chattonella calani*), *Paradinium*, *Ellobiopsis*, *Ichthyosporidium*, and early developmental stages of some Platyhelminths. Sections on *Paradinium* and the effects of plasmodial parasites are included.

5. FOOD AND FOOD-HABITS

See also **10, 11, 12, 33, 34, 108, 116**

86. Nicholson, C. (1937). "Moths eaten by bats." Entomologist, 70: 188.

32 additional species recorded in 1935 and 21 in 1936.

87. Campbell, J. W. (1937). "Birds taking moths." British Birds, 31: 122.

Further notes on this by **R. H. Brown**, *ibid.* 155–6.

88. Thomas, J. F. (1937). "Food of nestling swallows." British Birds, 30: 293–4.

Additions to previous lists. 10 species are recorded, of which eight were Diptera. The Bibionid *Dilophus febrilis* was the most abundantly and most frequently eaten.

89. Middleton, A. D. & Chitty, H. (1937). "The food of adult partridges, *Perdix perdix* and *Alectoris rufa*, in Great Britain." J. Anim. Ecol. 6: 322–36.

Crop contents and seasonal changes in food composition with notes of volume and occurrence. The food follows closely the seasonal cycle of plant life, depending largely on agricultural operations.

90. Dewar, J. M. (1937). "Herring gulls feeding on starfish." Scottish Nat.: 32, 81–2.

Notes on the methods by which *Larus argentatus* swallows *Asterias* and *Solaster*. (See also Oldham, *ibid.* (1937) 49–50.)

91. Carpenter, G. D. H. (1937). "Lizards as enemies of butterflies." Proc. R. Ent. Soc. Lond. A, 12: 157–61.

The point here stressed is the great rarity of marks on the wings of butterflies which can be attributed to the wide mouths of lizards, as compared with the acutely angled beak-marks of birds. Ten examples are mentioned, one of these, captured near Eastbourne, has a rounded mark on the left forewing possibly caused by a green lizard in the south of France or the Channel Isles!

92. Ritchie, A. (1937). "The food and feeding habits of the haddock (*Gadus aeglefinus*) in Scottish waters." Fisheries, Scotland, Sci. Invest., 1937, No. 2: 1–94. (Edinburgh: H.M. Stationery Office. Price 4*s*. 6*d*.)

Of Thompson's three main growth regions, that with the lowest growth rate (central North Sea) is found to be the area of least intense feeding. However between food consumption and growth rate there is often no correlation over small areas. Intensity of feeding is reduced in the spawning season. From Aug.–Dec. Crustacea and sand eels are taken in larger amounts. Seven specific feeding areas are described.

93. Savage, R. (1937). "The food of North Sea herring 1930–34." Ministry Agr. Fish., Fish. Invest. Ser. 2, 15, No. 5: 1–57. (London: H.M. Stationery Office. Price 3*s*.)

In the Shields area *Calanus finmarchicus* was the most important constituent of the food. The date and size of its maximum were closely related to the appearance and size of the herring maximum. The intensity of feeding was greatest in May, with a secondary maximum in August. The latter, though slight, is real, especially when the effect of temperature on rate of digestion is considered. In the northern North Sea *Calanus* composed only about a quarter of the total food, *Oikopleura* being the most abundant food animal. The small size and lateness of appearance of *Calanus* was responsible for poor landings in 1932. However, the 1932 broods were strong, whereas those spawned after the good feeding in 1931 were weak.

94. Fox-Wilson, G. (1937). "*Gryllotalpa gryllotalpa* Linn. in a Hampshire garden." Ent. Mon. Mag. 73: 162.

Cannibalism and other food habits of this mole-cricket.

6. POPULATIONS

See also **7, 8, 14, 22, 34, 51, 53, 73, 77, 78, 93, 115, 135**

95. Chitty, D. (1937). "A ringing technique for small mammals." J. Anim. Ecol. 6: 36–53.

Contains a review of previous studies of small mammal movements by marking methods; describes a new technique of live trapping and ringing, and discusses the interpretation of data thus obtained with especial reference to *Apodemus sylvaticus*, and to the use of marking methods for estimating population densities.

96. Lack, D. (1937). "A review of bird census work and bird population problems. (Adapted from a paper read to section D of the British Association, Blackpool, 1936)." Ibis: 369–95.

A valuable paper giving a comparative list of bird population densities in different types of habitat, using the recommended standard measure of number of adult birds per 100 acres. Human interference with nature appears to cause an increase in the numbers of individuals, though not of species. Methods of census taking, both absolute and relative, are discussed, as well as other problems including habitat variation, food, predators, disease, fecundity, population fluctuations, migration and territory. There is a large bibliography.

97. Vevers, H. G., Fisher, J., Hartley, C. H. & Best, A. T. (1937). "The 1937 census of gannets on Ailsa Craig; with notes on their diurnal activity." J. Anim. Ecol. 6: 362–5.

An increase of 24% on the previous year's census was found, localized in definite regions. Observations on the diurnal activity suggest relation between activity and wind, and the possibility of a rhythm.

98. Robinson, H. W. (1937). "Ringing puffins: good percentage of recoveries on breeding grounds." Scottish Nat.: 24.

Of 120 adults marked in 1937, on an island of the Orkneys, 17 bore rings of previous years. In 1935 individuals ringed as far back as 1928 were recovered. No recoveries were made in the winter quarters.

99. Philipson, W. R. (1937). "Two contrasting seasons at a redwing roost." British Birds, 30: 343–5.

Observations on a Northumberland roost of *Turdus musicus*. Flights to a communal roost were comparable to those made by rooks and starlings. The territory covered by members of this roost in 1934–5 was as great as in 1933–4, although the population density of the roost had considerably decreased.

100. Gladstone, H. S. (1937). "The decrease in blackgame in Dumfriesshire." British Birds, 31: 188–93.

Evidence suggests this may be due to the introduction of pheasants, against which blackgame are unable to compete in the struggle for the same ecological niche. On an area where pheasants were kept down, blackgame continued to flourish.

101. Middleton, A. D. (1937). "The population of partridges (*Perdix perdix*) in Great Britain during 1936." J. Anim. Ecol. 6: 318–21.

Data for nesting, summer sample counts, and shooting records on a number of estates. Nest density reached a maximum in 1936, but an unfavourable summer caused a high mortality among the young birds.

102. Ford, E. (1937). "The nation's sea-fish supply. Being the Buckland lectures for 1936." 112 small pp. Methuen & Co. Ltd., London. Price 3*s*. 6*d*.

Fisheries policy and the need for ecological research in planning conservation of the North Sea fish populations. (Reviewed in J. Anim. Ecol. (1937) 6: 395.)

103. Ministry of Agriculture and Fisheries (1936). "Salmon and freshwater fisheries. Report for the year 1935." 41 pp. (London: H.M. Stationery Office. Price 9*d*.)

This report gives the numbers and weight of salmon and migratory trout caught in 1935 in 27 fishing districts and summarizes the fluctuations in population of these fish since 1905. Furunculosis epizootics are discussed and it is suggested, in the case of the river Coquet, that improvements in fish passes, by permitting a wider distribution of the population, have diminished the intensity of the disease. Pollution and precautions against it are discussed and notice is given of simple methods of oxygen estimation for use by laymen. Relatively heavy and evenly distributed rainfall in 1935 lessened the damage due to sewage disposal. An experiment showed that trout are unable to live in artificially softened water, though the presence of only small quantities of natural hard water (about one thirtieth) keeps the fish healthy.

104. Powell, T. P. P. & Phillips, F. A. (1937). "Wye Board of Conservators: Annual Report, Season 1936." Hereford. 15 pp.

The rod catch of salmon for the season 1936 was, next to that of 1927, the best on record. Owners and lessees returned complete details on all but 146 of 5916 fish taken by rod. The average weight of these fish was 18·4 lb., the best represented group (66 %) being that from 15– < 30 lb. (approximately the 5-year-old class). The group 7– < 15 lb. (4 year olds) was 30 % of the rod catch. There was an unprecedented number of fish over 30 lb., but few grilse. Over 26 tons were netted in the estuaries. Furunculosis was again present.

105. Powell, T. P. P. & Phillips, F. A. (1938). "Wye Board of Conservators: Annual Report, Season 1937." Hereford. 15 pp.

In 1935 and 1936 the Wye experienced good fishing and the salmon rod catch was again easily ahead of those in other English and Welsh rivers. The 1937 season, however, was a very poor one not only in the Wye but in salmon waters throughout England and Ireland. The average weight of the fish taken by rod was 19·7 lb. (a record for the Wye) but this was largely because 5-year-old fish composed the bulk of the catch (80 %) as compared with 14 % of 4 year olds. Failure of the 4-year-old run has occurred as follows: 1918 (961 fish taken by rod and net); 1929 (1288 fish); 1930 (912 fish); 1937 (842 fish: less than one-quarter the average for the previous 5 years). This last failure cannot be attributed to bad conditions during the spawning, fry or parr stages. There seemed to be satisfactory numbers of fry, parr and smolts during 1937. Under nine tons were netted in the estuaries. Furunculosis was present for a fourth year.

106. Baweja, K. D. (1937). "The calculation of soil population figures." J. Anim. Ecol. 6: 366–7.

80–90 % of the soil fauna was found to be restricted to the top 9 in. of soil. It is suggested that samples be made of the size of 3 × 4 in. which is 2/1,044,440ths of an acre, so that calculation of individuals per acre may be facilitated.

107. Pickles, W. (1937). "Populations, territories and biomasses of ants at Thornhill, Yorkshire, in 1936." J. Anim. Ecol. 6: 54–61.

Weights and biomasses for 3 spp. A repopulation of the area disturbed in 1935 had taken place and the territories of the foraging species were found to be the same as for the previous year. *Formica fusca* was found to have the greatest weight (0·011 g.) per sq. m.

108. Carey, E. & Diver, C. (1937). "Territory in the yellow field ant, *Acanthomyops flavus*." J. Anim. Ecol. 6: 193–4.

Shows that this ant has a foraging territory and a preference for certain species of plants.

109. Hanson, H. S. (1937). "Notes on the ecology and control of pine beetles in Great Britain." Bull. Ent. Res. 28: 185–236.

Discusses the economic status of pine beetles in Britain, damage, occurrence of outbreaks, factors influencing the population, silvicultural treatment and forest hygiene.

110. Lysaght, A. M. (1937). "An ecological study of a thrips (*Aptinothrips rufus*) and its nematode parasite (*Anguillulina aptini*)." J. Anim. Ecol. 6: 169–92.

Distribution of this thrips in the "1856" plots at Rothamstead; seasonal distribution of thrips and degree of infestation, 1933–5, and the fluctuations in numbers of the host are discussed. The nematode is absent where there is a rank growth of the grass *Holcus lanatus*.

111. H[arrison], J. W. H. (1937). "The small ermine moth once more a nuisance." Vasculum, 23: 108.

After a period of comparative quiescence the small ermine (*Yponomeuta evonymellus*) has completed defoliated the bird cherry throughout the centre and west of Durham, and in Northumberland along the Tyne Valley.

112. Orton, J. H. (1937). "Oyster biology and oyster-culture. Being the Buckland lectures for 1935." 211 small pp. Edward Arnold and Co., Ltd., London. Price 5*s*.

The life history and autecology of *Ostrea edulis*. (Reviewed in J. Anim. Ecol. (1937) 6: 394–5.)

113. Orton, J. H. (1937). "Some interrelations between bivalve spatfalls, hydrography and fisheries." Nature, Lond., 140: 505–6.

A study on the Cark Sands in Morecambe Bay, together with findings of other workers on the Dogger Bank, show a tendency for *Cardium edule* and *Spisula* spatfalls and other organisms to become concentrated and precipitate in greatest numbers out of the plankton in localities where slack and eddy waters occur.

114. Pierce, E. L. (1937). "A plankton collector for fast towing." Nature, Lond., 140: 1014–15.

This inexpensive instrument consists of a diving fin to which is attached the plankton collector with an internal conical silk net. It is designed to collect living plankton quickly over a wide area and has proved practical when towed at a speed of eight knots. A full description is given together with a photograph of the apparatus.

7. MIGRATION, DISPERSAL, AND INTRODUCTIONS

See also **95**

115. Parsons, B. T. & Middleton, A. D. (1937). "The distribution of the grey squirrel (*Sciurus carolinensis*) in Great Britain in 1937." J. Anim. Ecol. 6: 286–90.

A comparison of the areas of distribution for 1930, 1935 and 1937 shows that the range continues to increase. The results are shown on a grid map.

116. Fraser, F. C. (1937). "Common dolphins in the North Sea." Scottish Nat.: 103–5.

Notes concerning five strandings on the east coast of England and Scotland in February 1937. Measurements of specimens are given. It is suggested that the dolphins followed cuttlefish which invaded the North Sea, and that the stranding of several sperm whale was due to the same reason.

117. Anon. (1937). "The future of the 'British Birds' Ringing Scheme: Transfer to the British Trust for Ornithology." British Birds, 31: 5–6.

This scheme, started in 1909, is steadily growing and responsibility for it has been undertaken by the British Trust for Ornithology, with headquarters at the British Museum. Enquiries to "Bird Ringing Committee, British Museum (Natural History), London, S.W. 7."

118. Witherby, H. F. (1937). "British Birds Marking Scheme. Progress for 1936." British Birds, 30: 337–42.

Over half a million birds ringed since 1909. Gives the numbers of 107 species ringed, with percentage of recoveries. Lists of persons participating.

119. Anon. (1937). "Recovery of marked birds." British Birds, 30: 254–8, 307–16.

120. Leach, E. P. (1937). "Recovery of marked birds." British Birds, 31: 112–19, 139–43.

Large lists giving date and place of ringing and recovery.

121. Witherby, H. F. & Leach, E. P. (1937). "Movements of ringed birds from abroad to the British Isles and from the British Isles abroad. Addenda V." British Birds, 31: 14–24, 42–53.

Additions, with notes, to the abundant records already published. Revised migration maps are given for heron, teal, wigeon, Manx shearwater and common and black-headed gulls.

122. Midlothian Ornithological Club (1937). "Isle of May Bird Observatory. Autumn Report, 1936." Scottish Nat.: 51–5.

A report on the general migration, ringing (300 adults of 42 spp.), weather conditions, with special notes on the yellow-breasted bunting, the Siberian lesser whitethroat and the northern willow warbler.

123. Midlothian Ornithological Club (1937). "Isle of May Bird Observatory. Spring report, 1937." Scottish Nat.: 126–8.

Report on general migration and weather conditions, 27 Mar.–29 May, and a note on the 449 adult and 13 young birds ringed (8 spp.).

124. Boyd, A. W. & Thompson, A. Landsborough (1937). "Recoveries of marked swallows within the British Isles." British Birds, 30: 278–87.

Young swallows, after fledging and before true migration sets in, disperse in all directions, though not to great distances. Yearling swallows seldom return to the exact spot where they hatched, but commonly to the same neighbourhood. Adult swallows generally return to the same place, often to the same nest as in the previous year.

125. Thomas, J. F. (1937). "Results of ringing and trapping swallows in Carmarthenshire." British Birds, 30: 294.

One male, ringed as an adult in 1931, returned in 1936 to nest within 20 yd. of its original site.

126. Robinson, H. W. (1937). "Recoveries of gannets from the Bass Rock." Scottish Nat.: 133–4.

Localities of 20 recoveries of birds banded since 1926.

127. Blockey, R. (1936). "Experiments with storks during 1936." Bird Notes and News, 17: 57–9, 91.

Attempt to rear storks from East Prussian eggs in a heronry in North Kent failed because the eggs were addled. Young storks sent from the Vogelwaree in Rossitten to the Haslemere Educational Museum lived successfully in Kent from June to August. By early November all had left for Africa *via* Isle of Wight or Land's End; two were killed passing through Normandy, indicating that eastern birds reared and released in the west took western migration route.

128. Anon. (1937). "Large immigration of waxwings in Scotland." British Birds, 31: 86–8.

Occurred in 1937 in February and March, instead, as is more usual, of October and November. Apparently the largest immigration since 1921–2, taking place mainly across S. Scotland from E. to W. as far north as Loch Ness. Notes on food habits.

129. Baxter, E. V. & Rintoul, L. J. (1937). "The immigration of waxwings in spring 1937." Scottish Nat.: 93–101.

An extraordinarily large migration into Scotland in Feb. and Mar. 1937 (which is late for this species); the birds spread rapidly about the country. Notes are on food and habits.

130. W[itherby], H. F. (1937). "The January–February influx of grebes and divers." British Birds, 30: 370–4.

Summary of replies relating to *Podiceps griseigena, nigricollis* and *auritus* and *Colymbus stellatus* and *arcticus*. The principal date of arrival in 1937 was January 31st, some birds remaining until April. This influx is from E. to W. and in 1937 most inland waters had one or two grebes. Tables are given of times and places of arrival and lengths of stay.

131. Temperley, G. W. (1937). "The 'summering' of a brambling near Newcastle." Vasculum, 23: 121.

On 18 September 1936 a brambling came to a bird-table and continued to visit the garden until 17 April 1937. It was seen again at intervals during the summer until the end of September. Normally this species migrates to the north in March or early April.

132. Wood, H. (1937). "Movements of herring in the northern North Sea." Fisheries, Scotland, Sci. Invest. 1937, No. 3: 1–49. (Edinburgh: H.M. Stationery Office. Price 2*s.* 6*d.*)

The author showed previously that in a mixed sample, races and communities of varied origin can be distinguished. If scales are correctly interpreted movements may be traced since the broods are thus naturally "tagged". The herring stocks, mixed together in the northern North Sea (NNS) for feeding during spring and early summer, split up in July:

Group	Spring and early summer	Latter half July	Mid-Sept. on
NNS adult autumn spawners	NNS then W. to N. and E. Shetland	S. to spawn off N.E. Scottish coast (1)	Leave coast. Some E. to Fladen ground (2)
NNS adult spring spawners	As above; greatest density further N. in Apr.–May	Seawards (4)	
SNS adult autumn spawners	Shetland and N.E. Scotland	Fladen ground (4)	S. to spawn (3)

(1) Joined by NNS spawners maturing for first time. These come from the opposite direction: E. coast estuaries and shallower waters of middle North Sea, their habitat during adolescence.

(2) Movements correspond with annual circular movement of water.

(3) Departure causes abrupt change in age composition.

(4) If these groups are numerous in spring and early summer the later catches on the Scottish grounds will be reduced, especially if the other group is small. This happened in 1930 when good landings up to 10 July were followed by some of the poorest for many years.

133. Menzies, W. J. M. (1937). "The movements of salmon marked in the sea. 1. The North-west coast of Scotland in 1936." Fisheries, Scotland, Salmon Fish., 1937, No. 1: 1–17. (Edinburgh: H.M. Stationery Office. Price 2*s.*)

Bag nets were used. Catches were best with an onshore wind and low water in the rivers. Four types of tags were tried; the best resembled a cattle ear tag. Movement in the Moray Firth is mainly of a restricted circulatory character. Short erratic journeys were made by restless fish waiting to ascend the Thurso River. 12 miles south of Cape Wrath the greatest number of salmon caught were proved by scale examination to be of very mixed origin; few were native to the local rivers. After release the fish scattered widely on their spawning migration to the rivers in which they were hatched. One quarter went south (as far as Mull, 150 miles); the rest went east (as far as Norway, 400 miles) or east and south (as far as Whitby, 410 miles). It is probable that up to Cape Wrath a common route had been followed from a feeding ground to the N. or N.W. Rates of travel were up to 33 miles per day.

134. Menzies, W. J. M. (1938). "The movements of salmon marked in the sea. 2. The West coast of Sutherland in 1937." Fisheries, Scotland, Salmon Fish., 1938, No. 1: 1–9. (Edinburgh: H.M. Stationery Office. Price 1*s.*)

448 salmon were caught, tagged and released 30 miles south of Cape Wrath. 13% were recaptured, $\frac{3}{5}$ on the north or east coasts, $\frac{2}{5}$ on the west. Recaptures were in rivers in which (as proved by scale peculiarities) the fish had been hatched. This confirms previous findings that the N.W. tip of Scotland is visited by salmon on a definite spawning migration route and that dispersion from here is not at random.

135. Nall, G. H. (1937). "Sea-trout of the River Conon." Fisheries, Scotland, Salmon Fish., 1937, No. 4: 1–31. (Edinburgh: H.M. Stationery Office. Price 2*s.* 6*d.*)

Scale reading was complicated by (1) the descent of some fish to brackish water for the last year or two of parr life, where open growth on the scales was made similar to that made by whitling in summer; (2) the occasional absence of a normal winter check due to good feeding; (3) occurrence of false checks due to irregular spring and summer feeding and (4) differences in abundance of food located in first two years after migration resulting in different scale growth. However, standards of average growth were made and interpretations checked by recaptures of marked specimens. Most (68%) migrate after three years of parr life (extremes two and five years) and most (52%) spawn in the second winter after migration (only 3% as whitling).

136. Stephen, A. C. (1937). "Recent invasion of the squid, *Todarodes sagittatus* (Lam.) on the east coast of Scotland." Scottish Nat.: 77–80.

A large number of strandings on beaches in Feb. 1937. There had been no storm. Squid were also abundant in the waters to the north of Scotland in 1930–1.

137. Grant, K. J. (1937). "An historical study of the migrations of *Celerio lineata lineata* Fab. and *Celerio lineata livornica* Esp. (Lepidoptera)." Trans. R. Ent. Soc. Lond., 86: 345–57.

The distribution and outbreaks of the sub-species *Celerio lineata lineata* in America, and *Celerio lineata livornica* in the Old World as far as they are known are described. It is suggested that both sub-species originate in semi-desert areas, and this idea is supported in the case of the American sub-species by showing that a correlation exists between outbreaks of the moths and a certain sequence of desert rainfall. No correlation is found between European outbreaks and the rainfall of those North African meteorological stations for which records are available, but this may be due to the paucity of suitable figures. A full account is given of the occurrence of *C. l. livornica* in Great Britain, and the main European outbreaks are listed. A correlation is given to show that years both of unusual abundance and of absence tend to occur simultaneously in Europe and America, and that the cause of outbreaks must therefore be sought in some factor common to the two continents. There seems to be some correlation between outbreaks and the sunspot cycle, but the figures are barely significant. The outbreaks tend to occur away from the sunspot minima.

138. Grant, K. J. (1936). "The collection and analysis of records of migrating insects, British Isles, 1931–5." Entomologist, 69: 125–31.

A discussion of the type of data required from observers; especially numerical estimates of abundance. Counts of indigenous species such as the small tortoiseshell are now being used as a control for comparison with counts of migratory forms.

139. Dannreuther, T. (1937). "Insect migration in May, 1937." Entomologist, 70: 165–6.

Pieris brassicae and *P. rapae* coming inland in large numbers along the north coast of Norfolk and in East Yorkshire from the North Sea against the wind. Also *Vanessa cardui* moving north from the South of England.

140. Dannreuther, T. (1937). "Migration records, 1937." Entomologist, 70: 176–80.

Records of insect movement during 1937. Further references in *id. et ibid.* 200–2; 228–31; 250–4.

141. Welti, A. (1937). "A collection of Lepidoptera taken between the Tower of London and the Monument, 1925–37." Proc. R. Ent. Soc. Lond. A, 12: 139.

Includes 7 migrants, 11 residents and 10 occasional species.

142. Beauchamp, R. S. A. (1937). "Rate of movement and rheotaxis in *Planaria alpina*." J. Exp. Biol. 16: 104–16.

Continues previous studies of *Planaria*. Feeding increases rate of movement for a period of about ten days. Sexually mature individuals respond positively to a weak current, and move at a faster and more irregular rate than do immature individuals. Negative rheotaxis is caused by strong stimuli or combined weak stimuli. Above 12° C. *P. alpina* responds positively to weak currents—a fact which explains the distribution of this species.

BRITISH ECOLOGICAL SOCIETY

SUMMER MEETING AT WRAY CASTLE, WINDERMERE, 28 AUGUST—1 SEPTEMBER 1937

By the kind invitation of the Council of the Fresh-water Biological Association and of the Director of the Station, the Society was able to hold its Summer Excursion at Wray Castle, Windermere. The organization of the meeting was kindly undertaken by the President, Dr Pearsall. About twenty-five members were present: some were accommodated in the Castle and some in Ambleside.

28 *August.* After dinner in the evening there was an informal meeting in the library of Wray Castle. Dr Pearsall gave an account of the general ecology of the area. He pointed out that the rocks are of three main types, the Borrowdale slates which are very hard and give steep acute hills and shallow soil, the Bannisdale slates which are softer and which give lower hills of rounder outline, and a deeper soil, and in the north, the similar Skiddaw slates. There is much superficial drift, and some outcrop of limestone to the south of Windermere. A series of lakes of glacial origin vary according to whether they lie in the softer or the harder rocks. For example, Windermere, which is in the softer rock, shows more silting and a richer vegetation. The high rainfall causes soil leaching which is marked on the deep soils, and has pronounced effects on the vegetation, although it is offset on steeper slopes by the effects of weathering and downwash.

Dr Pearsall pointed out that the area round Windermere has the highest percentage of natural woodland in Britain, consisting mostly of *Quercetum sessiliflorae* in a nearly natural condition. Man has exploited the woods until about eighty years ago for charcoal for iron smelting, producing coppice with standards, containing abundant hazel, birch and ash. Later there was bobbin and gunpowder manufacture. The exploited woods are very mixed, but the native woods have only occasional holly and birch under the oaks. There has also been marked deforestation from 1800 ft. downwards, by sheep grazing on the hillsides, and it was pointed out that this may have begun in prehistoric times, because all Bronze Age remains occur at 1000 ft. or more, save on the exposed western faces where they go down to 500 ft. The grazing is mostly *Agrostido-festucetum*, with *Nardus* where the drainage is locally poor.

The Director of the Station, Dr Worthington, gave an introduction to the work going on in the laboratory, indicating how the production cycles in Windermere were being investigated from many different angles. He briefly indicated the chemical measurements made by Dr Mortimer on the dissolved and suspended substances in the Lake, their seasonal variation and the recent detailed bathymetric survey of the lake by echo-sounding. He mentioned the work of plankton collection and algal culture, carried out by Dr Rosenberg, and the work of Dr Misra in relating rooted vegetation to the nature of bottom deposits. He showed that Misra's conclusion for plants had been extended by Mr Macan to water bugs, different species of which are associated with successive stages in the evolution of the lake-bottom deposits. Lastly he mentioned the work of Mr Allen on studies of the food and growth of fish, particularly of the perch in Windermere.

29 *August.* During the day the party had the opportunity of examining a long series of exhibits showing the work of the laboratory, and of discussing these with the staff. By duplicating the trip, it was made possible for all members of the party, to take part in an excursion on the lake in the Station launch.

Lake Excursion

Dr Pearsall and Dr Worthington gave a demonstration of the method of measurement of light penetration into the lake water by means of a Bernheim photoelectric cell lowered on a boom away from the boat. They demonstrated the typical logarithmic fall of light intensity with depth below the surface, and it was explained how light penetration is correlated with density of phytoplankton. It was shown that in a sequence of dry summers the reserves of nutrients in the lake are depleted and light penetration is great, but that rainy seasons, or sewage effluents, cause high phosphates and high nitrogen, with high phytoplankton density and less penetration. It was said also that the depth of rooted submerged Angiosperms depends directly on the light penetration.

The standard method of making a plankton haul was then demonstrated, and specimens were taken back for examination in the laboratory.

Dr Pearsall explained the factors which controlled the distribution of littoral phanerogams. Places with no silt had no plants, with young silt, abundant plants, and with an old, highly evolved, very organic bottom, again no plants. These features were demonstrated in Pullwyke Bay, which shows both a time succession and a zonation. The zonation showed *Phragmites* on the gravel shore, then a belt of *Carex inflata* and then *Scirpus lacustris* or *Equisetum limosum* on organic mud. The more inorganic silts showed *Potomogeton alpinus, Sparganium minimum* and *Elodea* with reed swamp of *Phalaris* and *Phragmites*. The more organic soils carried *Lobelia*, and in the reed swamp, *Equisetum limosum*.

30 *August*. The party visited Roudsea Wood and the adjacent peat moss. The moss is a typical example of a raised bog which has been severely drained and burned. The sphagnum surface is quite dead, but it retains the typical pool and hummock topography. *Myrica, Calluna* and *Erica tetralix* are now dominant with *Scirpus caespitosus* and *Eriophorum vaginatum* abundant, birch seedlings are scattered very abundantly over the bog surface, and the sloping margin of the bog next to the wood is covered with subspontaneous pine-birch wood. *Pinus* and *Betula pubescens* are dominant but make an open stand, and *Sorbus aucuparia* is frequent. The shrub layer is a continuous sheet of very tall *Vaccinium myrtillus*. *Myrica Ilex*, and *Dryopteris dilatata* are occasional. These pine woods are on the edges of all the mosses, and Pearsall regards them as the relics of native woods; they grow on very highly oxidized and very acid peat of *p*H 2·8–3·2. *Pteridium* is local on disturbed and less acid soil of *p*H more than four, often with *Molinia, Hypnum cupressiforme* and *H. schreberi*. In residual wet places on the bog surface the following mosses were recognized, *Sphagnum papillosum, S. plumulosum, S. tenellum, Campylorus flexosus, Dicranella cerviculata*.

Roudsea Wood itself showed a remarkably complex and interesting vegetation related to a striking alternation of limestone outcrops through deeper calcareous clay becoming locally more or less acid. On the clays the woods were of oak-ash type with oak standards and ash copice. *Betula, Alnus, Quercus robur*, and sycamore were present with *Rubus saxatilis, Paris quadrifolia, Melica uniflora, Convallaria majalis*. The deeper soils carry *Brachypodium sylvaticum* and *Mercuralis perennis*. The sharp limestone outcrops were dominated by *Taxus*, but also carried abundant *Alnus, Corylus, Fraxinus, Euonymus, Tilia cordata*, and *Sorbus aucuparia*, with mosses such as *Hypum molluscum* and *Neckera*, and *Convallaria* in the shallow soils.

Where the wood was traversed by a deep valley, an old arm of the sea, there was a wide deposit of alkaline peat maintained by calcareous drainage water. It showed a sequence from *Phragmitetum* through a tussock swamp of *Carex paniculata* to fen wood dominated by *Alnus* and *Frangula alnus*. In many places both the reed swamp and fen wood had been cut, giving the very characteristic fenland patchwork, with all the typical fenland species. On the drained and cut slopes of the valley, the fen peat had become acid, and was covered with

Molinia with *Deschampsia flexuosa* and *Galium saxatile*, or with tall *Pteridium*: *Alnus* and *Betula* were colonizing it rapidly.

On the far side of the valley was fairly primitive oak wood on slate, which had undergone some felling but no coppicing. There were no trees but oak, but there were occasional shrubs of *Ilex*, *Betula*, *Sorbus aucuparia*, and *Tilia cordata*. The shallower soils carried *Rubus*, *Deschampsia flexuosa*, *Galium saxatile*, *Luzula pilosa* and *Teucrium scorodonia*. On the deeper soils there was *Pteridium* with some *Scilla* and *Holcus*, and on the rocky outcrops *Vaccinium myrtillus* with characteristic mosses such as *Mnium hornum*, *Hypnum cupressiforme*, *Dicranum majus* and *Hylocomium loreum*. There were conspicuously more mosses and ferns on the north- and south-facing slopes.

From the wood the party made its way to the shore of the estuary which was bordered by fragments of sandy salt marshes. Locally these marshes gave indications of a transition through *Phragmitetum* into fresh-water fen. After tea the party visited a strip of woodland on thin dry peat about nine inches thick overlying estuarine silt. Here *Betula pubescens* was dominant, with *Acer pseudoplatanus* frequent and *Taxus* rare. On the floor *Dryopteris dilatata* and *Scilla* were abundant, and it was suggested that the fern was the chief peat former.

31 *August*. The zoologists of the party visited Stickle Tarn, a series of peat pools at altitudes from 500 to 2000 ft., and examined the transition from lowland to alpine fauna.

The botanical party was taken to Tarn Howes, on the margin of which they examined a small drainage bog containing a mixture of oligotrophic and eutrophic species. The lake, with water of low hardness, has a Desmid plankton and contains *Litorella*, *Lobelia*, *Elodea*, *Potomogeton natans*, and *Myriophyllum spicatum*. The party then followed the outflow stream from the lake down to the Ambleside-Coniston road, examining on the way the bryophytes of the stream bed, and the fragments of primitive woodland on the valley slopes. Submerged in the stream were *Fontinalis antipyretica*, *Eurhynchium rusciforme*, *Alicularia scalaris*, and *Scapania*. In the splash zone were *Porotrichum alopecurum*, *Brachythecium rivulure*. Abundant on rock slopes by the beck were *Hymenophyllum unilaterale*, *Plagiothecium undulatum*, *Dicranum majus*, *Hylocomium loreum*, on sloping *damp* rock surfaces were *Campylopus atrovirens* and *Rhacomitrium protensum*, and on rock surfaces with acid drainage water *Blechnum*, *Diplophyllum albicans* and *Sphagnum* (?) *quinquefarium*.

The fragments of primitive wood had a very open stand of *Quercus sessiliflora* with marginal *Betula alba*, and a small amount of *Sorbus aucuparia* and no shrubs, or sparse hazel or holly. There were abundant seedlings of *Betula*, *Sorbus*, *Fraxinus* and *Quercus*, but few seedlings were surviving. The ground was completely carpeted with vegetation, mostly mosses. The Phanerogams included *Vaccinium*, *Galium saxatile*, *Potentilla erecta*, *Deschampsia flexuosa*, *Melampyrum hians*, *Oxalis acetosella* and *Pteridium* and *Anthoxanthum* on deeper soils where the slope is less and the soil of *p*H about 4·0. The ferns included *Blechnum*, *Lastraea oreopteris*, *Dryopteris filix mas* and *Hymenophyllum unilaterale*. The mosses included *Dicranum majus*, *Hylocomium loreum*, *Plagiothecium undulatum*, *Polytrichum commune*, *Dicranum scoparium*, *D. fuscum*, *Hypnum schreberi*, *H. cupressiforme*, *Sphagnum* spp., and *Leucobryum*.

The party then ascended Tilberthwaite Gill. The scree contained *Cryptogramme crispa*, *Saxifraga aizoides*, *Asplenium trichomanes*. The gorge was densely clothed with a scrubby woodland containing abundant woody species, but very little oak. The party did not stay to examine the wood but climbed through it to the *Agrostis-fescue* pastures of the fell top, and as rain began to fall made their way down from the ridge to the Gill.

The sincerest thanks of the Society are due to those who made possible such an interesting and instructive excursion and most of all to the President, whose extraordinary knowledge of the ecology of the area was so unsparingly put at our disposal. We shall remember with great pleasure this most successful of excursions. H. G.

ANNUAL MEETING AT THE BOTANY SCHOOL, CAMBRIDGE
7–9 January, 1938

Soirée in the Botany School

On the evening of Wednesday, 5 January, between eighty and a hundred members and guests were entertained at a soirée in the Botany School.

A large number of interesting exhibits was shown in the laboratory. Dr A. S. Watt showed a large portion of a bracken rhizome extracted and mounted to exhibit its rooting depth in the soil and its general morphology. This was supplemented by smaller specimens and diagrams. Dr D. H. Valentine showed herbarium and living specimens of British primulas, violas and *Potentilla reptans*, hermaphrodite female plants of *Glechoma hederacea*, and the two sexes of *Petasites vulgaris*, together with a map showing their distribution in the British Isles. Mr M. H. Clifford had set out a collection of mosses from the growing bog surface of the raised bog at Tregaron, Cardiganshire. Dr Butler demonstrated a hygrometer for measuring micro-humidity gradients at the surface of a transpiring leaf under different external conditions of macro-environment. He showed at the same time an evaporimeter for measuring the evaporating power of the air at different heights above, and at various points on, the leaf surface, under different atmospheric conditions. Dr V. M. Conway showed an auxanometer apparatus employed in the field to obtain continuous records of the extension growth of the leaves of *Cladium mariscus*, together with results showing the daily and seasonal drifts of such growth at Wicken Fen. Dr H. Godwin had put out exhibits showing peat samples from various types of blanket bog and raised bog found in this country, and lantern slides illustrating the appearance, structure, and communities of such bogs. In particular there were diagrams showing the stratigraphy of the large raised bog at Tregaron, Cardiganshire. There were also shown examples of the application of pollen-analysis technique to peat deposits at Tregaron, and from the submerged peat beds of the North Sea. Mr G. C. Evans demonstrated a field potometer of the type he employed in ecological measurements in the Nigerian rain-forest, and a controlled condition experimental chamber. Mr P. Falk showed an exhibit illustrating the ecology of central Iceland, a vegetation map of the eastern slopes of the volcano Snaefell, transects and photographs. Dr P. W. Richards put out photographs of vegetation of the Middle Atlas, Morocco, and an exhibit of the growth forms of Bryophyta in tropical rain-forest. Mr Martin showed a vegetation map of the Kalahari sands of Northern Rhodesia, and herbarium specimens from the area. There had also been set out an illustrated account of the itinerary of the Friday excursion, which included an air photograph showing the extinct course of the Little Ouse river meandering as a "roddon" through the peat fens.

The Annual Meeting

The twenty-fourth annual meeting of the Society was held in the Botany School, Cambridge, on the following morning, Thursday 6 January, at 10 a.m., the President, Dr W. H. Pearsall, occupying the chair. The minutes of the previous Annual Meeting were read and confirmed. The report of the Honorary Secretary was read and adopted.

Hon. Secretary's Report for the year 1937

The twenty-third Annual Meeting of the Society was held in the Department of Botany, University College, London, on 9 January. On the evening of Friday, 8 January, about ninety members and guests were entertained to a soirée in the Department, where an exhibit of wide interest had been arranged.

The Annual Meeting was held on the 9th, and after transaction of business six very interesting papers were read to the Society. The warm thanks of the Society are due to Prof. Salisbury and Hill, who gave us the use of their Department and made arrangements for us in the usual generous manner.

The Summer Excursion of the Society was held at the Freshwater Biological Station Laboratory, Wray Castle, Windermere, from 28 August to 1 September. About twenty-five members were present, and took part in excursions to the Lake, to peat bogs, woods and to the local mountain pastures. We are much indebted to the Director and staff of the Station, who spared no trouble to make the meeting so enjoyable, and particularly to our President, Dr Pearsall, who made arrangements for the meeting, and most competently led the excursions.

In the past year two numbers of volume six of *The Journal of Animal Ecology* have been published, appearing in May and November. They contained respectively 238 and 184 pages, thus maintaining the substantial dimensions reached by volume five. Thirty original papers were published with eleven plates, in addition to notes, notices and reviews. Notices of publications on Animal Ecology in this volume totalled 307.

Since the last Annual Meeting there have been issued two numbers of *The Journal of Ecology*, appearing in February and August, and containing respectively 288 and 290 pages, with twenty-five plates. In this volume have been published twenty original papers, as well as notes and book reviews.

The end of this year is marked by the resignation of Prof. Tansley from the editorship of *The Journal of Ecology*. He has edited the *Journal* since the retirement of Dr Cavers. In his capable hands the *Journal* has steadily increased in size and importance, and the Society owes him the profoundest gratitude for his long and valuable service.

The Society's transplant experiments at Potterne are continuing satisfactorily in the hands of Mr Marsden Jones and Dr Turrill.

Since the last Annual Meeting the membership of the Society has risen from 343 to 350. Fourteen members have resigned or have died, and 21 new members have been elected. Of the present membership list 189 members receive *The Journal of Ecology* alone, 111 *The Journal of Animal Ecology* alone, 50 receive both *Journals* and one neither.

During the year the Council of the Society has been asked to interest itself in the National Parks movement, and it has sent representatives to committees called to advance the objects of this movement.

Dr Burtt Davy then spoke of Prof. Tansley's work as editor of *The Journal of Ecology*, paying tribute to the devotion and care with which he had carried out his duties. A vote of thanks to the retiring editor was carried with acclamation. The following elections and resignations were proposed from the chair, and carried *nem. con.*: elected new members, Messrs Dundas, Hope-Simpson, Piemeisel, Burges, Harley, Miss Carey, Mrs Brindley, the Wellington School Natural History Society: resigned, Messrs Eden, Longstaffe, Blair, Gilbert, and Pledge.

The alterations of rules proposed by the Council were explained by the President and Hon. Secretary, and being put from the Chair, were carried *nem. con.* They are as follows:

Rule 8 to read: "The Society shall be governed by a Council of not less than fifteen, and not more than twenty Members, consisting of the Officers of the Society, namely, the President, two Vice-Presidents, the two Hon. Editors, the Hon. Secretary, the Hon. Treasurer, and the Hon. Assistant Treasurer, with ordinary Members of Council."

Rule 14 to read: "The Hon. Assistant Treasurer shall be responsible for collection of subscriptions, shall assist the Hon. Treasurer, shall hold office for three years, and shall be eligible for re-election."

The meeting then proceeded to the election of officers as follows:

President: Prof. A. G. Tansley, F.R.S. (retiring, Dr W. H. Pearsall).
Vice-President: Dr A. C. Hardy (retiring, Prof. Salisbury).
Hon. Editor Journal of Ecology: Dr W. H. Pearsall (retiring, Prof. Tansley).
Hon. Editor Journal of Animal Ecology: Mr C. S. Elton.
Hon. Secretary: Dr H. Godwin.
Hon. Assistant Treasurer: Dr A. S. Watt. (See changes of rules proposed.)
Ordinary Council Members: Dr A. R. Clapham, Mr G. H. Bates, Dr E. W. Jones, Mr C. Diver, Mr A. D. Middleton, Dr F. T. K. Pentelow.
Retiring: Dr Leach, Prof. Boycott, Mr Wilmott.
Not retiring: Prof. Salisbury, Mr Oldham, Dr Russell, Dr Ashby.

Dr Pearsall then retired from the chair, and said in so doing how happy the Society was to welcome back to that office Prof. Tansley, who had been its first President, twenty-five years ago. Prof. Tansley, taking the chair, thanked the Society for the honour done him.

The Secretary then outlined suggestions for a single-day meeting at Bedford College at Easter, and for a Summer Excursion at Aberystwyth.

In the absence of further private business the meeting proceeded to the reading of papers.

Capt. C. Diver described the origin and purpose of the Association for the Study of Systematics, and explained what the Handbooks Committee of that body was doing to correlate the work of Ecology, Genetics, and Cytology with Taxonomic work. He asked for the support of the Society.

Mr J. Dundas read a paper on "Vegetation changes in the Sahelian zone of the southern Sahara". He described three main types of vegetation: Savanna thornland, Acacia scrub on indurated soils, and Fringing Forest on the damper soils by water courses. He also described the vegetational zonation round Lake Chad, an interesting example of regeneration of Acacia round new wells, and the marked association of *Tamarindus indica* with the baobab tree. A lively discussion followed, in which Dr Burtt Davy, Dr Godwin, Dr Burges, Mr Middleton, Capt. Diver, Prof. Tansley and Prof. Osborn took part.

Mr J. Ford then read a paper on the food of young partridge chicks, describing the results of crop-analyses from birds of different ages. There was an extremely well-marked change in diet at the end of three weeks, from entirely animal to largely vegetable food. He concerned himself mostly with analysis of the animal food, and drew attention to sources of error in interpreting results based on too few indices of presence. There was evidently much individual variation between birds caused by differing season and opportunity. Capt. Diver, Mr Middleton, Mr Wilmott, Dr Turrill and Mr Blackman took part in the discussion which followed.

Mr J. D. Martin then gave an account of the Baikiaea plurijuga forest and other vegetation types of the northern extension of the Kalahari Sands into North Rhodesia. The area lies north-west of the Livingstone Falls, at an altitude of 3000–3500 ft., and has very uncertain rainfall. The soils vary greatly in respect of the relative proportion of fine and coarse materials in them, and therefore in water-retaining power. It was shown how this affected vegetational distribution. Particular interest attaches to Baikiaea plurijuga, the dominant of one extensive forest type, since it is a deciduous, tap-rooted species of a genus otherwise limited to tropical (evergreen) rain-forest. Mr Martin suggested that this forest type had formerly been more widespread than at present, attributing this to climatic change, accelerated by fire, grazing etc. Dr Burtt Davy and Prof. Adamson spoke in the discussion after the paper.

Dr Burtt Davy then opened a discussion on nomenclature of Forest Communities in the Tropics. He indicated the conflict between existing systems such as those of Chipp and of

Champion, and circulated a draft conspectus for the African forests. The discussion which followed revealed both strong feeling that standardization would be extremely useful, and also a desire not to make premature commitments in instances where principles were not yet understood. Prof. Adamson, Dr A. S. Watt, Dr Richards, Prof. Osborn, Mr Wilmott and Mr Day spoke in the discussion. The meeting finally approved the proposal of the Hon. Secretary that the matter be referred to the Council for consideration by a special committee.

After the adjournment for lunch, the Hon. Treasurer made a provisional statement of the financial position of the Society. This was accepted as satisfactory, and a vote of thanks to the Hon. Treasurer, proposed by the President, was carried unanimously.

It was proposed from the chair, and carried *nem. con.*, that Messrs William Norman and Son be reappointed auditors for the ensuing year. Grants of £5 to the Transplant Experiments of the Society, and of £10 to the Freshwater Biological Association, were similarly approved.

Dr P. W. Richards then gave an account of stratification in a tropical rain-forest with only a single dominant. It was based on work done by Mr T. A. W. Davis of the British Forestry Department, Guiana. Dr Richards showed that the general characteristics of irregular outline, and stratification of woody plants into three or more layers, which is typical of mixed rain-forest, give place to smooth canopy and two storeys of woody plants where there is dominance by a single species. The President and Mr Holttum raised questions afterwards.

Mr P. Falk continued with an illustrated account of the Ecology of Central Iceland. He described mountain slope vegetation on lava soils at about 2000 m. He showed the pronounced effects of varying slope and soil depth, and of snow duration upon the vegetation. The reality of solifluction phenomena was demonstrated by ash-bands due to the volcanic eruption of 1783. In the wetter areas interesting examples of pool and hummock formation were described and the discussion, which followed, turned largely upon this. Mr Marquand, Mr Wilmott, Dr Polunin, Dr Clapham and Dr Turrill spoke.

Dr A. S. Watt then gave an account of some aspects of the autecology of the Bracken fern, concerned with excavation of the rhizome system. He showed how the system is a series of lateral shoots, produced in zig-zag fashion, and though small plants 88 and 68 ft. long had been measured, in another one lateral alone had produced over 200 ft. of rhizome. Dr Watt described the changes of density and rhizome depth across the invasion front of an area of bracken, correlating this with the appearance of the community. In the discussion the President, Mr Baker, Mr Summerhayes, Mr Montford, Dr Turrill, Capt. Diver and Mr Wilmott spoke.

Dr W. H. Pearsall then proposed on behalf of the Society very sincere thanks to Prof. Brooks for having given the hospitality of his department, and for providing the evening soirée. This was carried with acclamation. Dr Pearsall also thanked the Secretary and his assistants for the trouble taken in arranging the meeting.

On the following morning, a party of thirty, under the leadership of Dr Godwin and Mr Tidmarsh, made an excursion by 'bus through the south-eastern fens and the Breckland margin. In the fenland special attention was called to the buried pine forest horizons, the upper and lower peats separated by fen-clay, and the large silt "roddons" which represent the course of extinct rivers in Romano-British to pre-drainage times. The party crossed the Fen-Breck margin between Kenny Hill and Lakenheath, and had lunch on Maidscross Hill overlooking Lakenheath Warren. During lunch Mr Tidmarsh explained the communities visible, and the party then walked across the heath to meet the 'bus on the Brandon road. The party reached Cambridge just after 2.30 p.m.

BRITISH ECOLOGICAL SOCIETY

REVENUE ACCOUNT FOR THE YEAR ENDING 31 DECEMBER 1937

Income

	£	s.	d.	£	s.	d.
Subscriptions received, including arrears	516	18	1			
Less Prepayments for 1938–9	27	5	0			
	489	13	1			
Less Transferred to *Journal of Animal Ecology* (see below)	195	2	6			
				294	10	7
Interest on Investments	34	10	0			
Interest on Deposit Account	1	0	4			
				35	10	4
Journal of Ecology—Sales, etc.:						
Current volume, xxv, 1937	561	18	6			
Back volumes and parts	41	15	1			
Sales of reprints	65	9	6			
Fee for use of photograph	1	1	0			
	670	4	1			
Grants received from: £ s. d.						
University of London 40 0 0						
Ministry of Agriculture and Fisheries 10 0 0						
Government of Mauritius ... 50 0 0						
	100	0	0			
				770	4	1
Index Volume, *Journal of Ecology* (vols. i–xx), Sales				30	18	0
Journal of Animal Ecology—Sales, etc.:						
Vol. vi, 1937: Subscriptions received	195	2	6			
Sales	227	5	7			
Sales of reprints	39	13	9			
Vols. i–v: Sales of back numbers	98	6	10			
	560	8	8			
Grant from Carnegie Corporation of New York, through the Bureau of Animal Population, Oxford University	10	0	0			
				570	8	8
				£1701	11	8

Expenditure

	£	s.	d.	£	s.	d.
Working Expenses:						
Printing, Circulars, etc.	4	12	0			
Postages	8	3	8			
Bank Charges		16	2			
Clerical Assistance (Secretary and Treasurer) ...	15	0	0			
				28	11	10
Audit Fee				3	3	0
Grant:						
British Ecological Society's Transplant Experiments Fund				5	0	0
Soirée Expenses				3	7	11
Journal of Ecology, vol. xxv (1937):						
Paper, Printing, Illustrations, etc.	736	1	0			
Binding	2	1	0			
Carriage, Insurance, Postages, etc.	48	14	3			
Publishers' Commission	84	4	6			
				871	0	9
Index Volume, *Journal of Ecology*, vols. i–xx:						
Carriage, Insurance, Postages	6	12	7			
Publishers' Commission	3	1	10			
				9	14	5
Journal of Animal Ecology, vol. vi (1937):						
Paper, Printing, Illustrations, etc.	508	13	3			
Publishers' Commission	49	3	3			
Carriage, Insurance, Advertising, etc.	27	11	9			
Fee for Special Review	5	0	0			
				590	8	3
				1511	6	2
Balance, Surplus for the Year				190	5	6
				£1701	11	8

BALANCE SHEET AT 31 DECEMBER, 1937

Liabilities

	£	s.	d.	£	s.	d.
Membership Subscriptions, prepaid for 1938, etc....				27	5	0
Journal of Animal Ecology, vol. vi, pt. 2:						
Printing Account due	221	8	7			
Less Sale of reprints	24	7	6			
				197	1	1
Library Account				1	5	0
General Revenue Account, Balance of Funds:						
Balance at 31 December 1936	897	5	9			
Add Surplus for year ending 31 December 1937	190	5	6			
				1087	11	3
				£1313	2	4

Audited and found correct and as shown by the Account Books of the Society. The Bank Balances have been verified by Bank Certificates.

(Signed) WM NORMAN & SONS.

120, Bishopsgate, London, E.C.2. *Chartered Accountants.*

Assets

	£	s.	d.	£	s.	d.
Westminster Bank—Credit Balances:						
Current Account	47	9	4			
Deposit Account	350	0	0			
				397	9	4
Investments:						
£700 3½ % War Loan at cost (Market value at 31 December 1937 at 101½ = £710. 10*s.* 0*d.*) ...	717	3	0			
£200 5 % Conversion Loan at cost (Market value at 31 December 1937 at 114½ = £229)... ...	198	10	0			
				915	13	0
				£1313	2	4

NOTE. A further asset is the unsold Stock of the *Journals* and Index Volumes, held for the Society by the Publishers.

(Signed) HUGH BOYD WATT,

LIST OF MEMBERS (January 16th, 1938)

E. = Takes *The Journal of Ecology*. A. = Takes *The Journal of Animal Ecology*.

Corrections, omissions or changes of address should be notified at once to the *Hon. Secretary*, Dr H. Godwin, Botany School, Cambridge.

E. A. **Adams**, Dr Charles C.; New York State Museum, Albany, N.Y., U.S.A.
E. **Adamson**, Prof. R. S., M.A.; The University, Cape Town, S. Africa.
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